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FINAL REPORT

20 KILOVOLT ROCKET BORNE ELECTRON ACCELERATOR

Prepared by:

Ion Physics Corporation
Burlington, Massachusetts

Prepared for:

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas

Contract NAS9-10399

November, 1973

ION PHYSICS CORPORATION

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Robert Harrison

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ACKNOWLEDGEMENTS

Many thanks to Mr. Charles (Buddy) Salisbury, our project technician, and Mr. Ernie Wienschenk, our mechanical engineer. The contribution made by these individuals and the spouses of the crew is greatly appreciated.

ROCKET BORNE
20 kV ELECTRON ACCELERATOR

The accelerator system is a preprogrammed multi-voltage system capable of operating at a current level of 1/2 ampere at the 20 kilovolt level. The system is a self-contained, gas insulated unit designed to be flown on a Strypi IV rocket. There are five (5) major functional areas which comprise this system which are as follows:

(1) Silver Zinc Battery Packs
(2) The Electron Gun Assembly
(3) Gun Control and Opening Circuits
(4) The Telemetry Conditioning Section
(5) The Power Conversion Section

Most of these areas can be seen in the photo shown in Figure 1-1. Briefly, the silver zinc batteries are located at the bottom of the package, contained in their own stainless steel boxes.

The electron gun assembly which consists of guns, sockets and vacuum feedthroughs is the top most deck. Just below the electron gun assembly, in the middle of the package, are the gun control circuits. The modular high voltage converters are located on the outer edge of the deck just below the electron gun assembly, with transistor bridge drivers one deck below.

Figure 1-1. 20 Kilovolt Half Ampere Rocket Borne Electron Accelerator.

SECTION 1
SILVER ZINC BATTERY PACKS

Power at 28 V, for the complete system, with the exception of 100 - 200 mA, provided by the NASA instrumentation section for interface commands, was supplied by two silver zinc batteries contained in pressure-vacuum tight boxes. Each battery was assembled from 39 cells, internally connected to provide either a positive or negative output. In addition to the total series cell voltages selected inter-cell taps provided other voltage levels.

The schematics of the Batteries D 1055-123 and D 1055-124 indicate other features such as blanket heaters and pressure sensors.

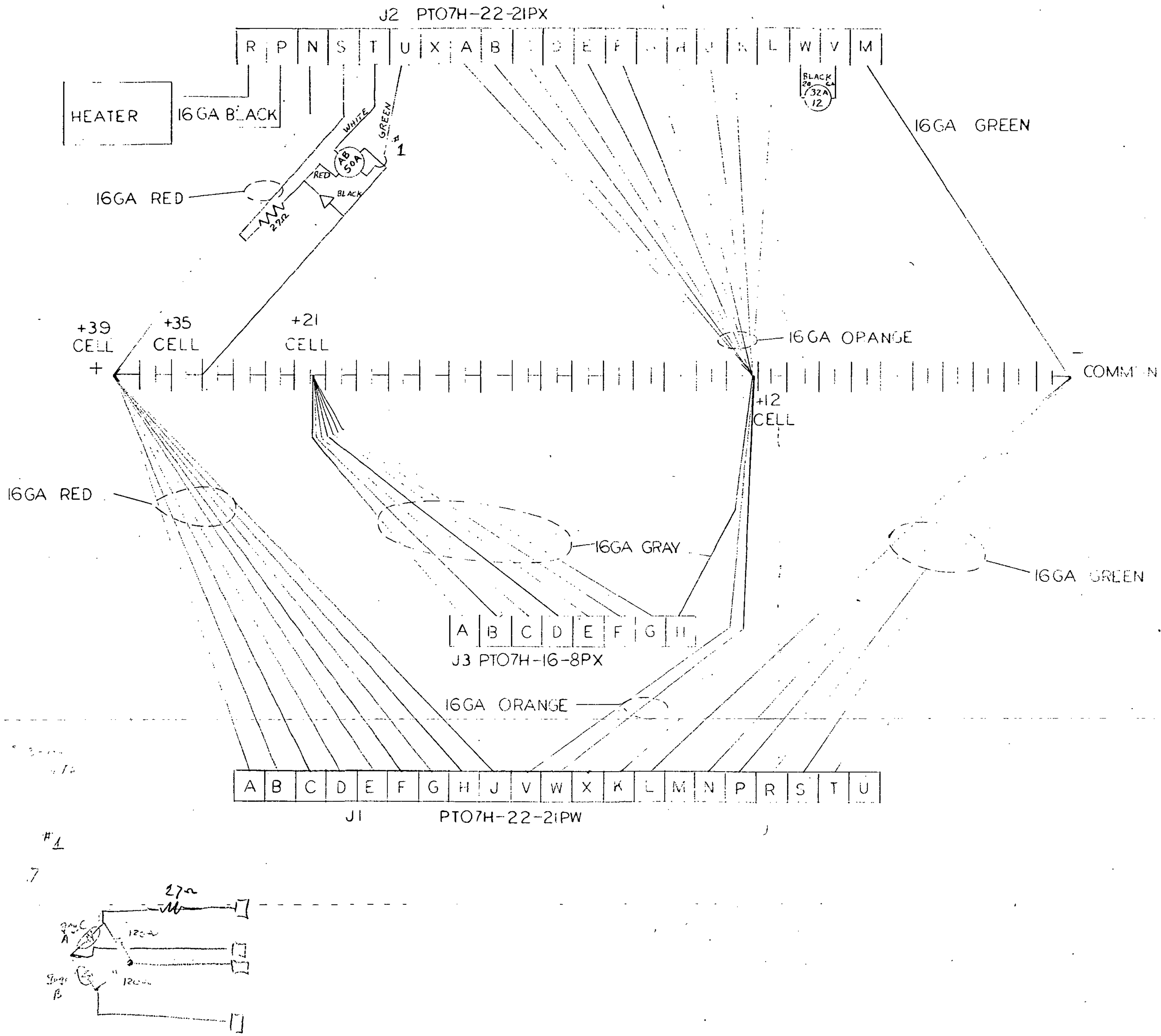


Figure 1-2. Positive Battery Schematic (D1055-123)

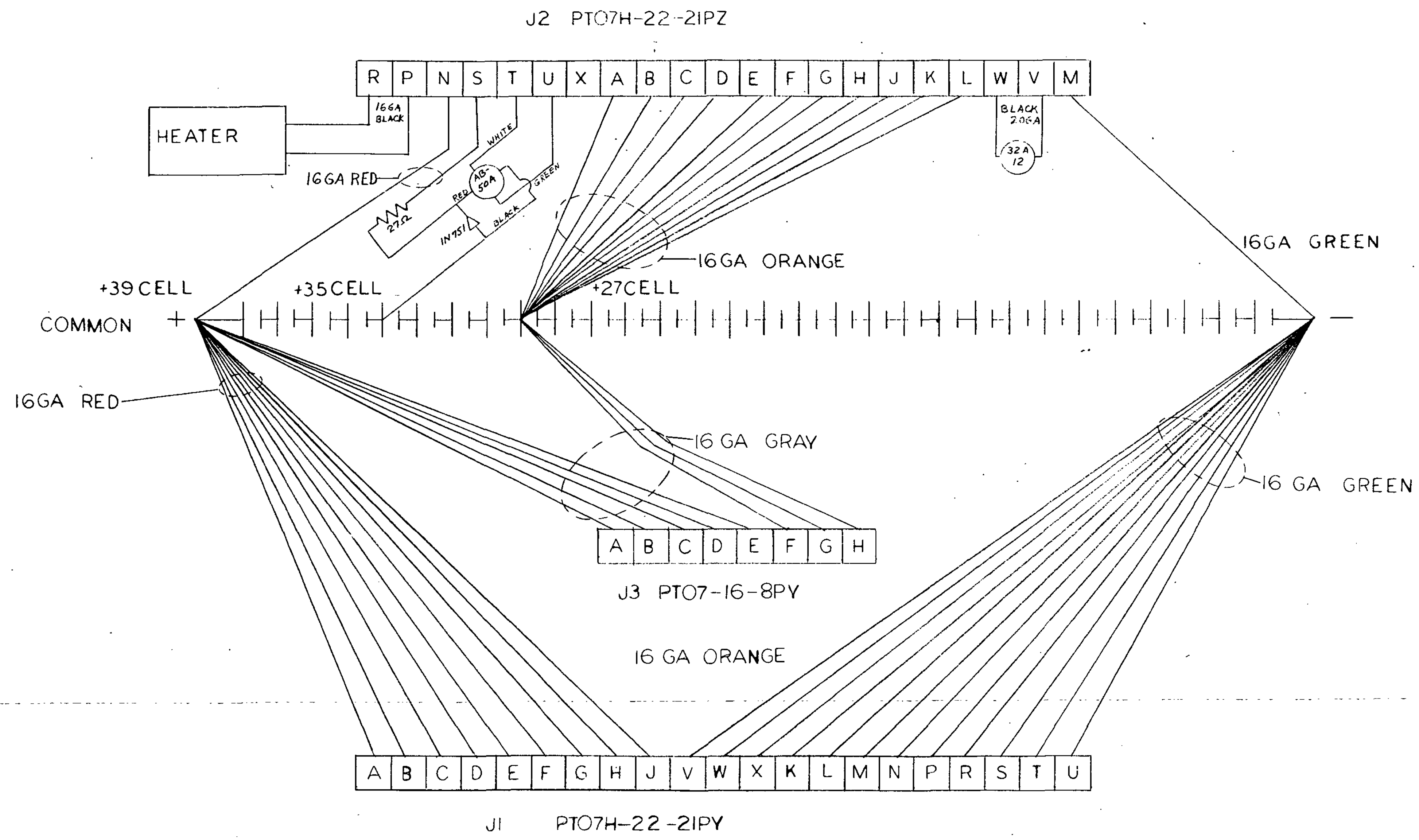


Figure 1-3. Negative Battery Schematic (D1055-124).

SECTION 2
ELECTRON GUN ASSEMBLY

The Electron Gun Assembly is constructed on an aluminum deck which serves as a vacuum-pressure interface. The deck and outside skin were designed to withstand the force of the nose cone eject spring mechanism which provides an axial force on the geometric center of the deck.

The electron guns, six in all, are mounted around the outside edge of the deck in bored holes and insulated from the deck in order to measure intercepted electrons.

The gun connection sockets are mounted concentrically around each hole on the inside of the package. The sockets are fabricated from standard "Jettron" electron tube connection fixtures set into carefully radiused electrodes supported by polypropylene insulating spacers. All H.V. electron gun cabling was clamped to the cathode filament connection electrode for each gun. The inner area of this electrode also provided a convenient point to mount limiting resistors and suppression capacitors.

The deck was also bored in three places to permit the mounting of a vacuum feed-thru flange. Each of the three feed-thru flanges provided high current connections for two electron gun opening bands as well as the anode and cap current monitor connections. This flange is shown in Figure 2-0.

The electron guns used for the conjugate experiment was an evolutionary extension of the guns from the first experiment. In order to upgrade the EE65 to meet the new requirements, Machlett Laboratories increased the length of the gun and replaced the second control grid with an anode.

The modification to the gun structure made it necessary to investigate the effects of the physical changes on electron optics of the gun. (See Reference Appendix F.)

Figure 2-1 and 2-2 show the EE65 and the modified EE65, designated EE65-1 respectively.

The EE65-1 remained unchanged in the area of the gun opening. The same EE65 electrically induced thermal shock method would be employed. The cleanliness and reliability of this method had been adequately demonstrated.

Figure 2-3 shows the internal EE65-1 gun structure. This gun is basically the same as the EE-65 design, however, changes have been made in order to use an $.8\,cm^2$ cathode rather than the $.38\,cm^2$. It was also necessary to enlarge the pre-accelerator assembly as a result of this large cathode.

Also the spacing between the pre-accelerator and the cylindrical anode was increased to .200" (inches) for increased electrical holdoff strength in order to operate at 20 kV.

One of the major reasons for the selection of a "triode" type gun was the beam divergence over a wide range of operating voltages.

As part of the program, an extensive beam optics study was performed. Figures 2-4 and 2-5 summarizes this study.

Figure 2-4 is the transfer characteristics for a typical gun and Figure 2-5 indicates the average angle of divergence for three operating voltages versus pre-accelerator voltages.

The electron guns are operated in a cathode follower mode. This mode of operation is inherently stable from parasitic oscillators and provides a convenient method of current selection, i.e., that of changing the cathode resistor value.

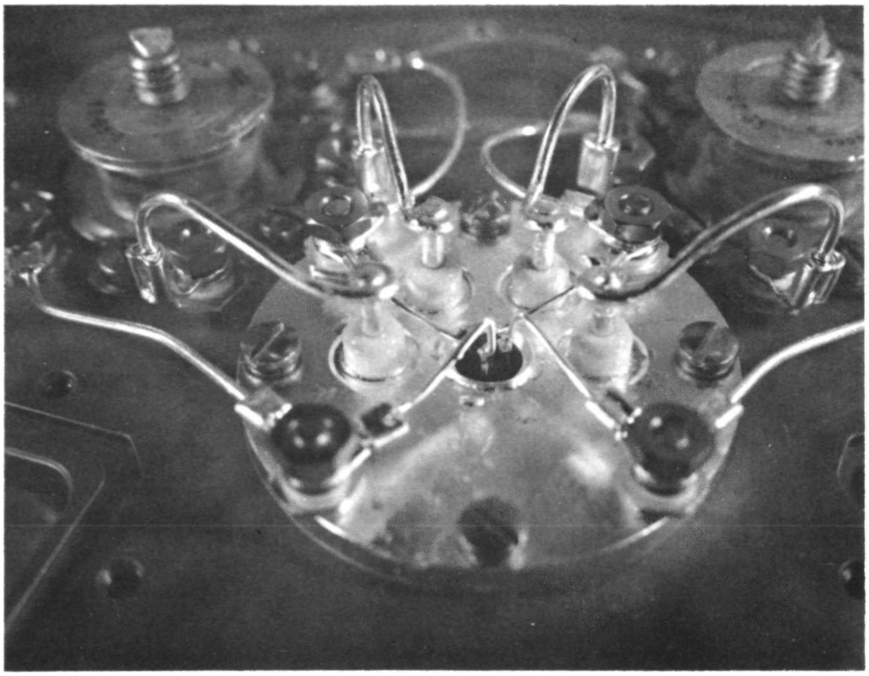
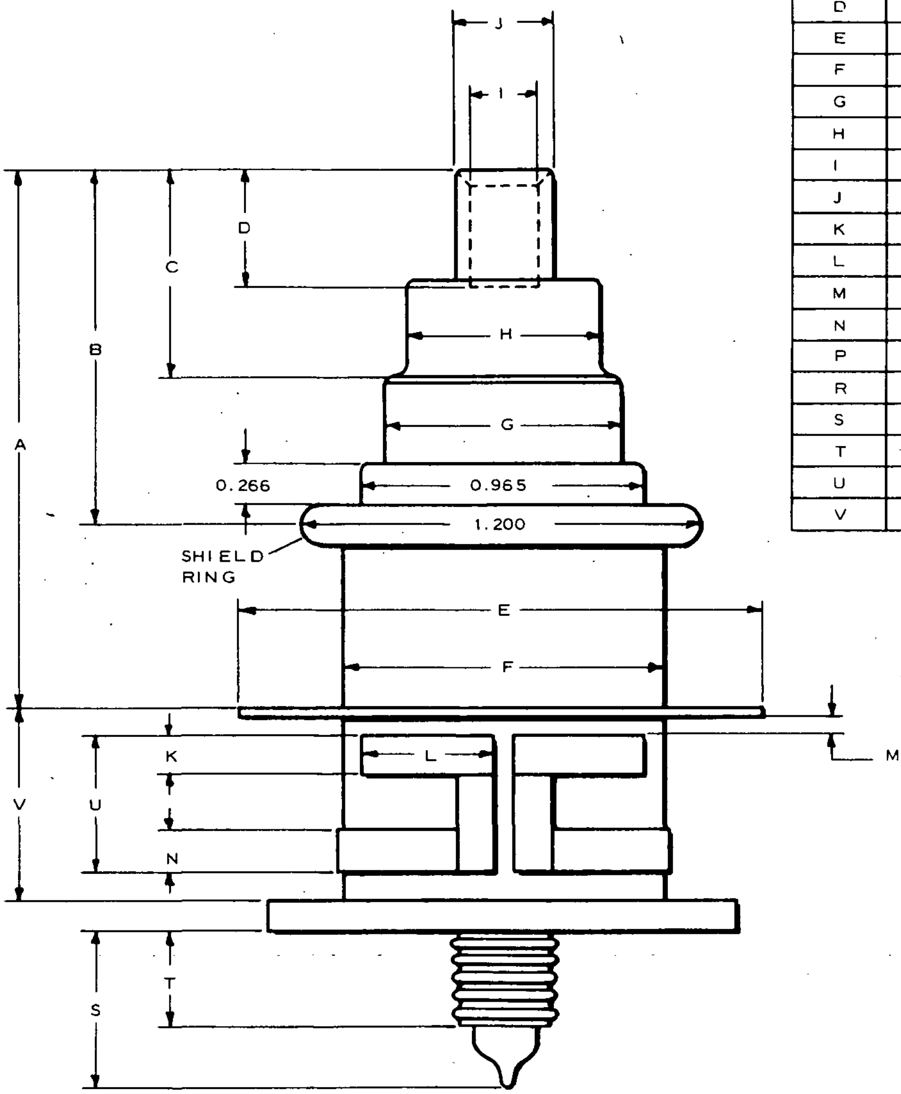
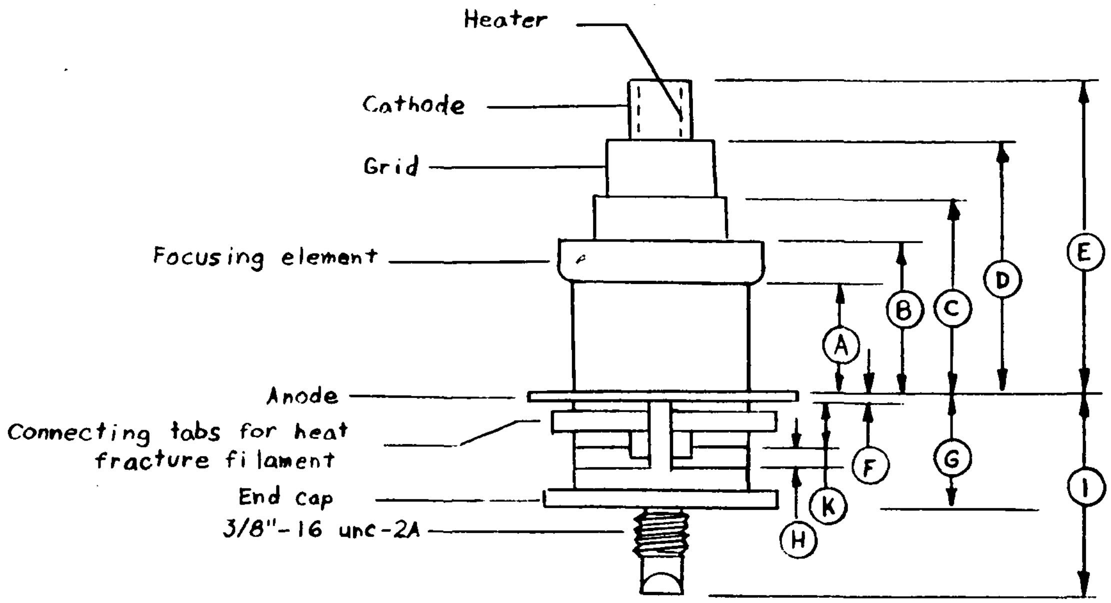


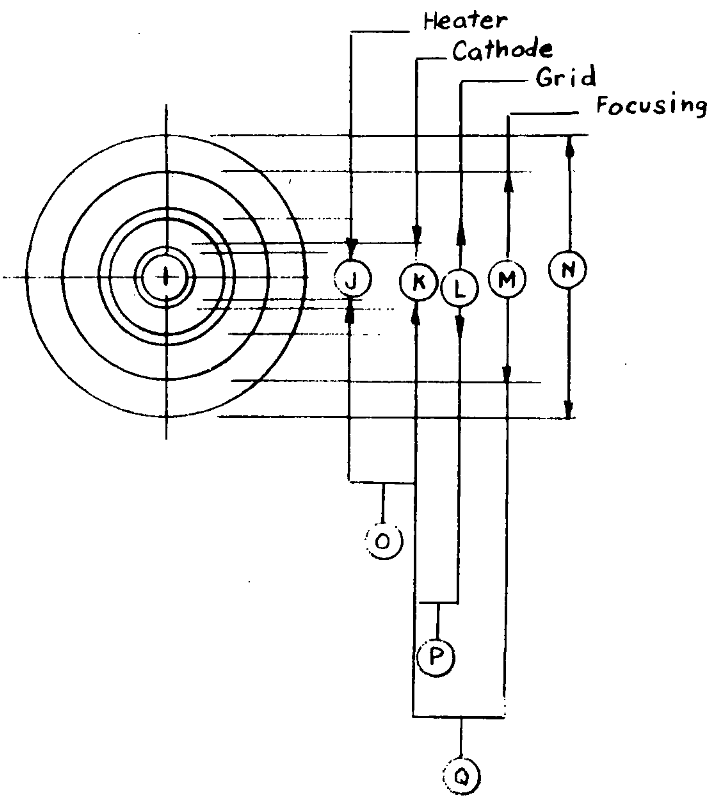
Figure 2-0. Vacuum Feedthrough.



DIMENSIONAL SPECS.		
DIM.	MIN.	MAX.
A	1.652	1.695
B	1.082	1.139
C	.632	–
D	.328	–
E	1.660	1.668
F	1.015	1.035
G	–	.795
H	.655	.665
I	.210	.220
J	.310	.325
K	.125	.140
L	1-1/8	–
M	.065	.075
N	.125	.140
P	.67	.69
R	.060	.075
S	1/2	–
T	5/16	–
U	3/8	–
V	9/16	–

Figure 2-1. Machlett EE-65 Electron Gun Configuration.





	Dimensions in inches		
	Minimum	Nominal	Maximum
A	.592	.612	.632
B	.833	.848	.863
C	1.085	1.100	1.115
D	1.425	1.440	1.455
E	1.784	1.804	1.824
F	.049	.050	.055
G	.660	.677	.690
H	.110	.140	.145
I	—	—	1.300
J	.210	.218	.220
K	.310	.317	.325
L	.655	.660	.665
M	1.194	1.200	1.206
N	1.660	1.661	1.668
O	—	—	.010 TIR
P	—	—	.015 TIR
Q	—	—	.025 TIR
R	.250	.300	.325

Figure 2-2. EE-65-1 Electron Gun Outline.

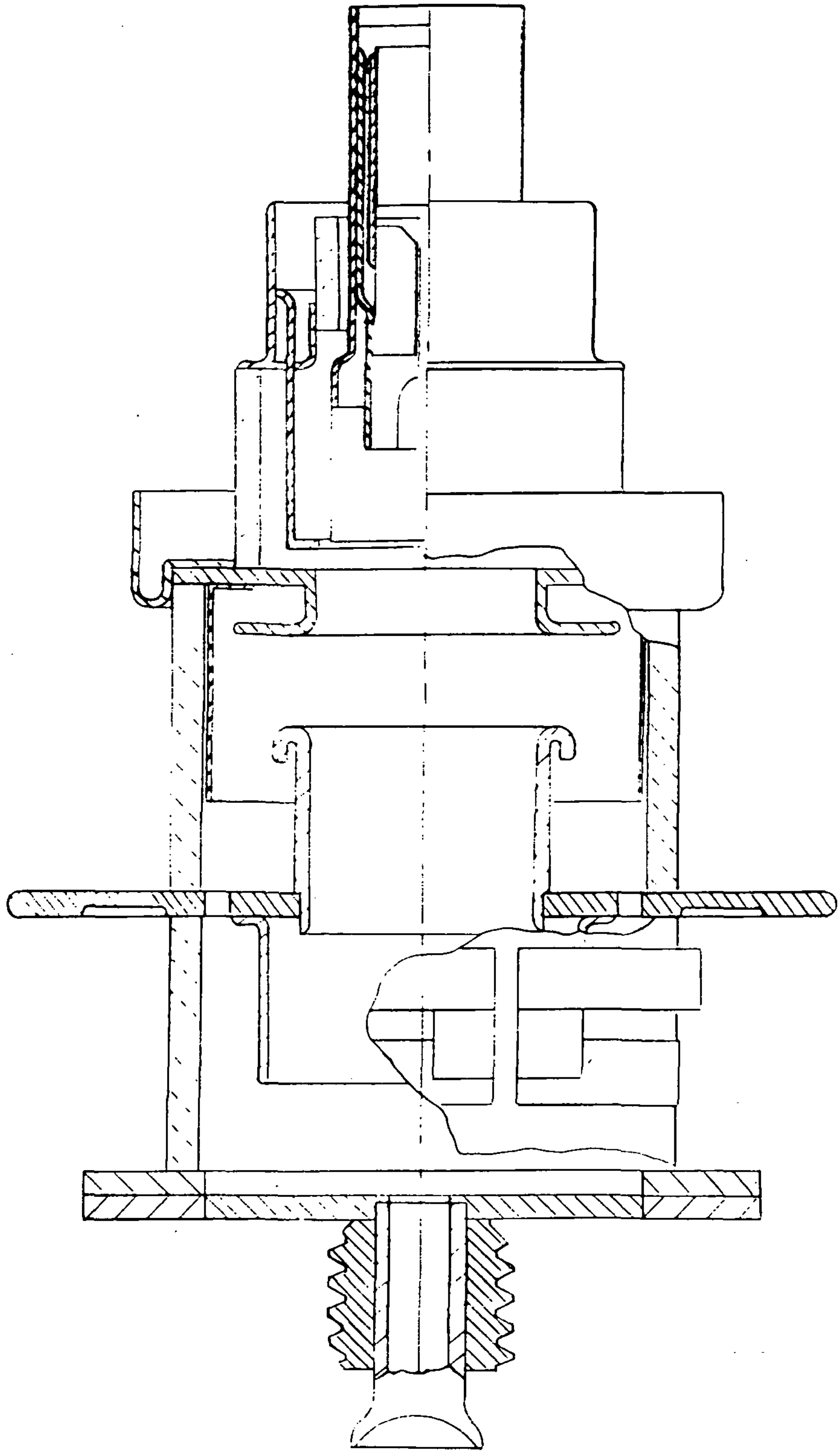


Figure 2-3. EE-65-1 Internal Structure Outline.

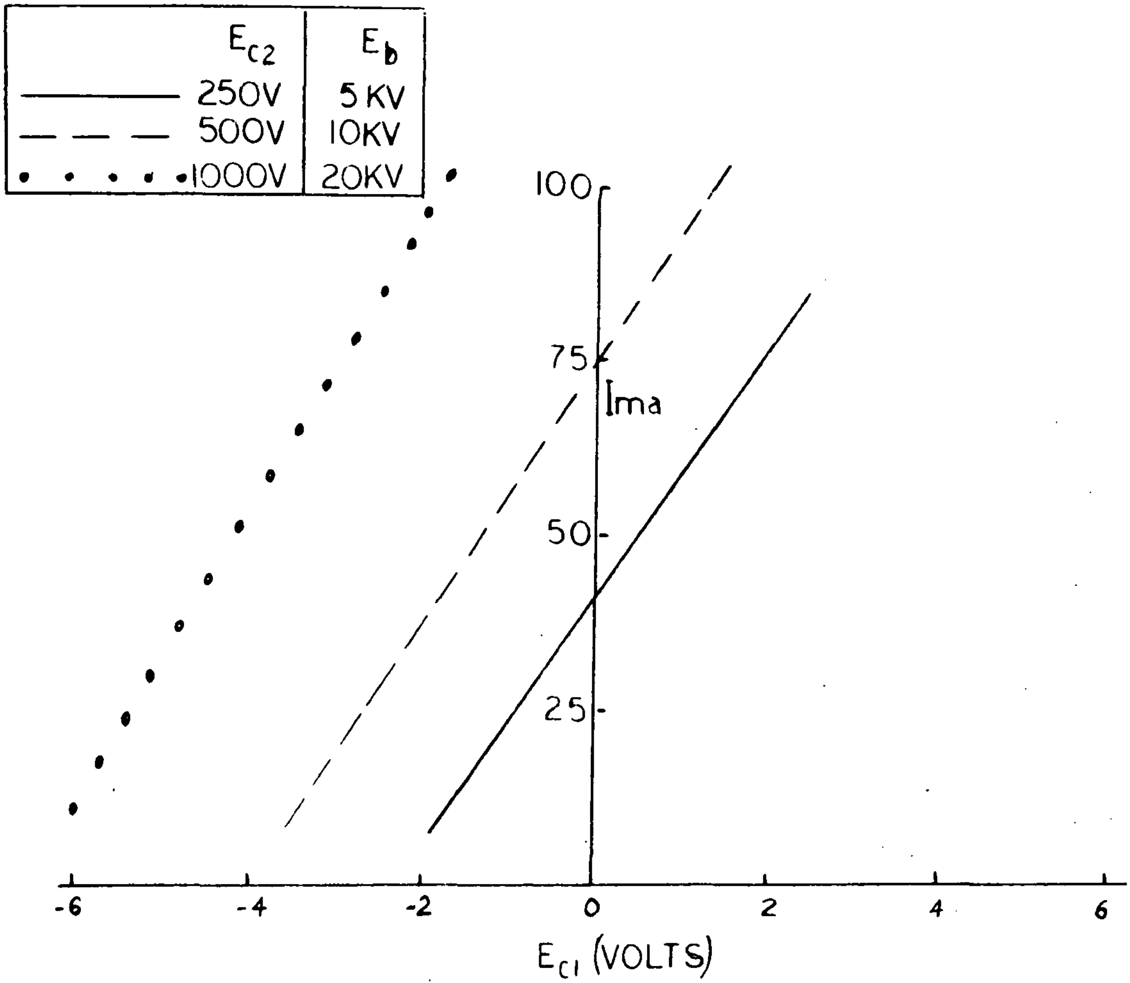


Figure 2-4. Gun #4 Transfer Characteristics.

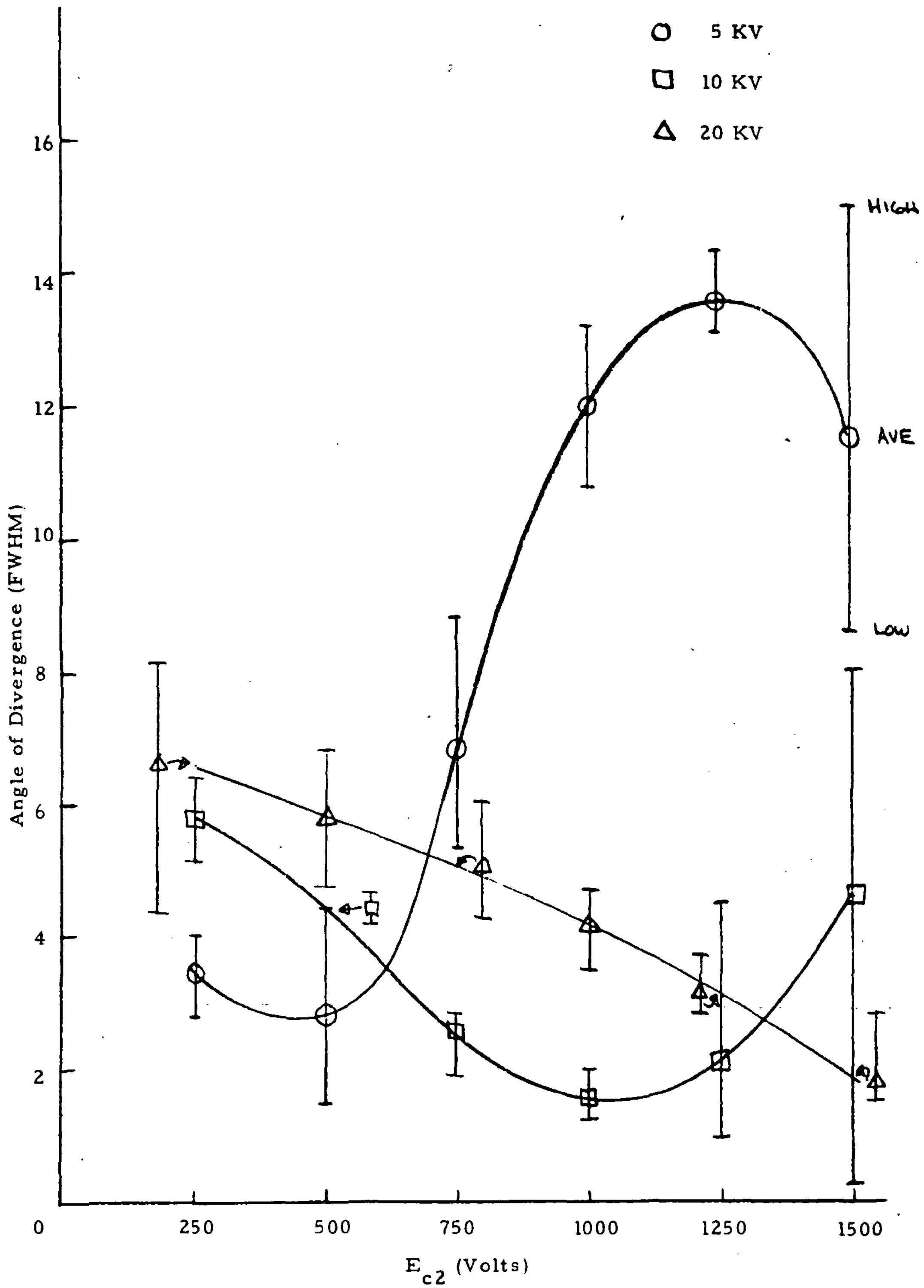


Figure 2-5. Average Optics.

SECTION 3
GUN CONTROL CIRCUITS

The electron guns are controlled by an electro-mechanical program mer which reproduces the specified flight program.

The flight program is listed in Table I. The programmer is designed to repeat the sequence of 44 pulses continuously. The interaction of the programmer with the other portions of the system can best be seen in Figure 3-1.

Basically, the flight performance is initiated by two Goddard Space Flight Center (GSFC) commands. The first being the filament "On" command, the second being the experiment "On" command. The experiment "On" command starts the flight programmer.

Once started the programmer will cycle through the gun opening sequence after which the program of gun voltage and current shown in Table I begins.

The filament power is supplied from the positive main battery pack via a drive oscillator and an isolation transformer. The filament voltage is controlled by regulation of the battery voltage to the filament converter unit.

The resulting filament voltage remained constant as the filament represents a constant load. The schematic of the filament current converter is shown in Figure 3-2.

Power for the grid bias is also supplied via the filament converter.

In the event one or more electron guns would not open during the opening sequence, it was important to keep that gun(s) from operating. This was accomplished by the circuit shown in Figure 3-3. The cap of each gun was attached to a spring which served not only to remove the cap after the gun was opened but also as a switch which would keep the unopened gun cut-off.

The Programmer Schematic is shown in Figure 3-4. The unit was designed to be immune to RFI and EMI generated within the accelerator by high voltage breakdowns.

TABLE I

Pulse No.	Voltage (kV)	Current (mA)	Duration (sec)	Start of Each Pulse with Reference to Start of Pulse 1 in (sec)
1 A	20	500	.01	0.00
2 A	20	500	1.0	1.73
3 A	20	500	1.0	3.95
4 A	20	200-500	2.0	5.96
5 A	20	500	1.0	9.99
6 A	20	200	1.0	12.00
7 A	20	500	6.0	14.03
8 A	20	500	.01	22.19
9 A	20	500	1.0	24.10
10 A	20	500	1.0	26.12
11 A	20	200-500	2.0	28.13
12 A	20	500	1.0	32.18
13 A	20	200	1.0	34.20
14 A	20	500	.01	36.31
15 A	20	200	.150	38.24
16 A	20	200	1.0	39.24
17 A	20	500	1.0	41.30
18 A	20	200	.01	43.38
19 A	20	500	.150	44.30
20 A	20	500	1.0	46.32
21 A	20	500	1.0	48.33
22 A	20	500	1.0	50.34
23 A	20	200-500	2.0	52.36

TABLE I (Concluded)

Pulse No.	Voltage (kV)	Current (mA)	Duration (sec)	Start of Each Pulse with Reference to Start of Pulse 1 in (sec)
24 A	20	500	1.0	56.32
25 A	20	200	1.0	58.42
26 A	10	500	.01	60.52
27 A	10	200	.15	62.45
28 A	10	200	1.0	63.48
29 A	10	500	1.0	66.50
30 A	10	200	.01	67.60
31 A	10	500	.15	68.52
32 A	20	500	1.0	70.54
33 A	20	500	1.0	72.56
34 A	20	500	1.0	74.60
35 A	20	200-500	2.0	76.62
36 A	20	500	1.0	80.64
37 A	20	200	1.0	82.66
38 A	*5	500	.01	84.80
39 A	*5	200	.15	86.70
40 A	*5	200	1.0	87.71
41 A	*5	500	1.0	89.72
42 A	*5	200	.01	91.84
43 A	*5	500	.15	92.76
44 A	20	500	1.0	94.78
1 B	-	-	-	96.90

*actual 6 kV due to switching

3.1 Gun-Opening (Break-Seal) Circuits

The gun opening band requires about 15 V at 60 amperes for 2 - 3 seconds. In the system this power is supplied from a voltage tap on the main batteries. Switching is accomplished with transistor switches which are turned on in sequence by a Ledex rotary solenoid switch. The circuits are shown schematically in Figure 3-5. High power germanium transistors are used throughout. The circuit design is predicated on several major criteria, determined during the development phase of the program. The first is the necessity to keep voltages appearing in the vacuum environment (and on the bands consequently) as low as possible with respect to the structure voltage. The second is the requirement that the vacuum environment, particularly at the power feedthrough headers do not see at any time voltage differences greater than 15 volts.

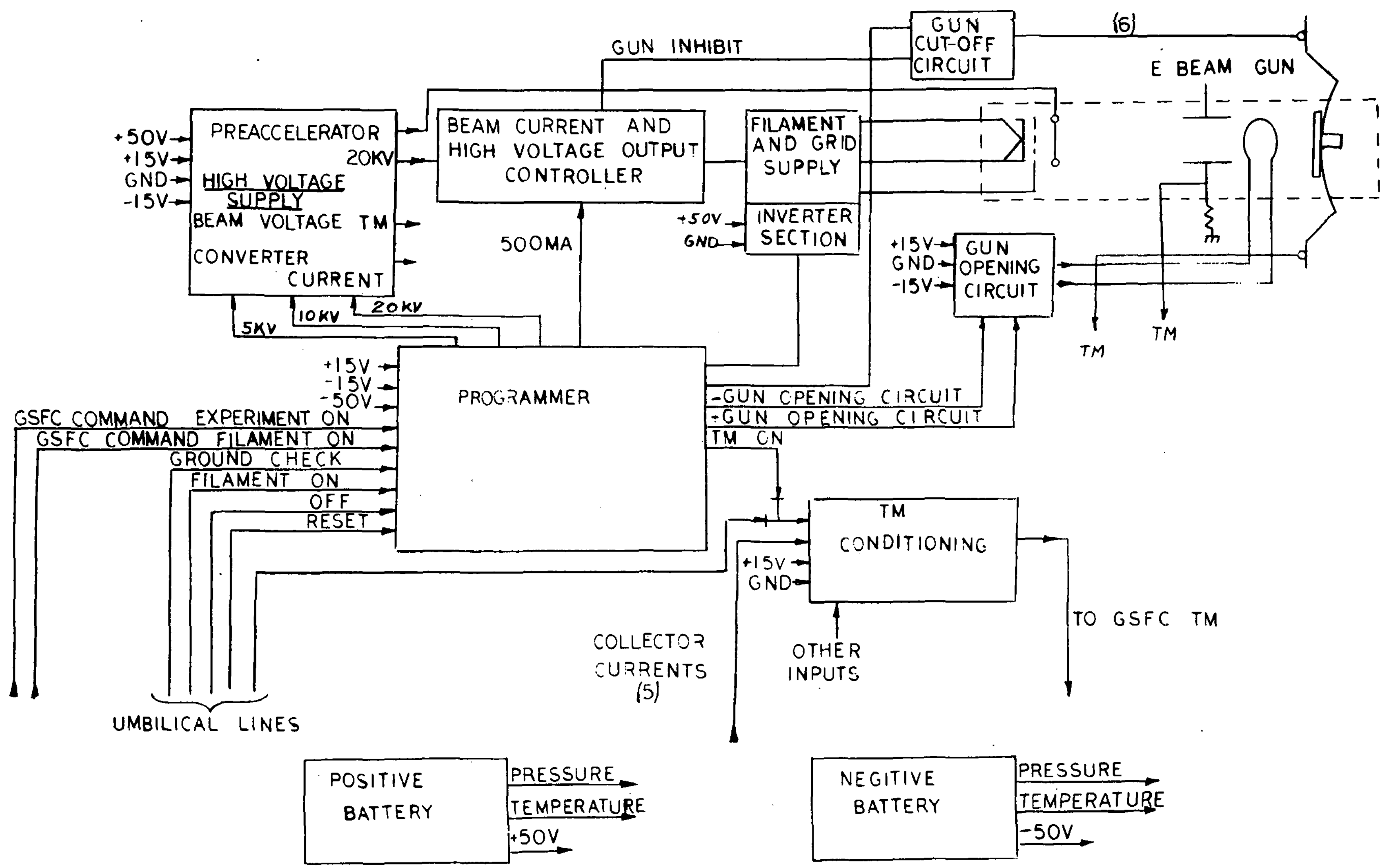


Figure 3-1. 20 kV Accelerator System Block Diagram.

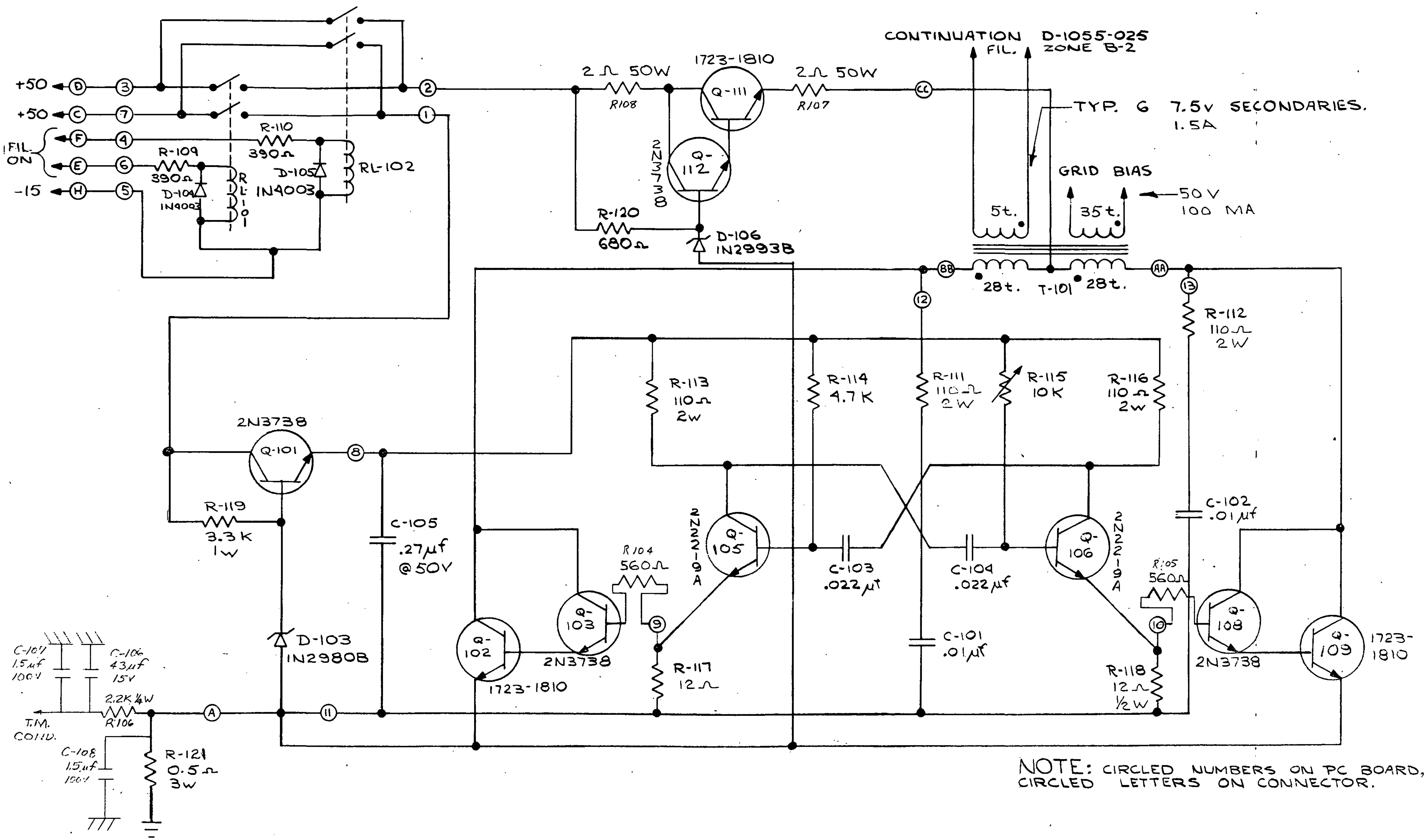


Figure 3-2. Filament Converter.

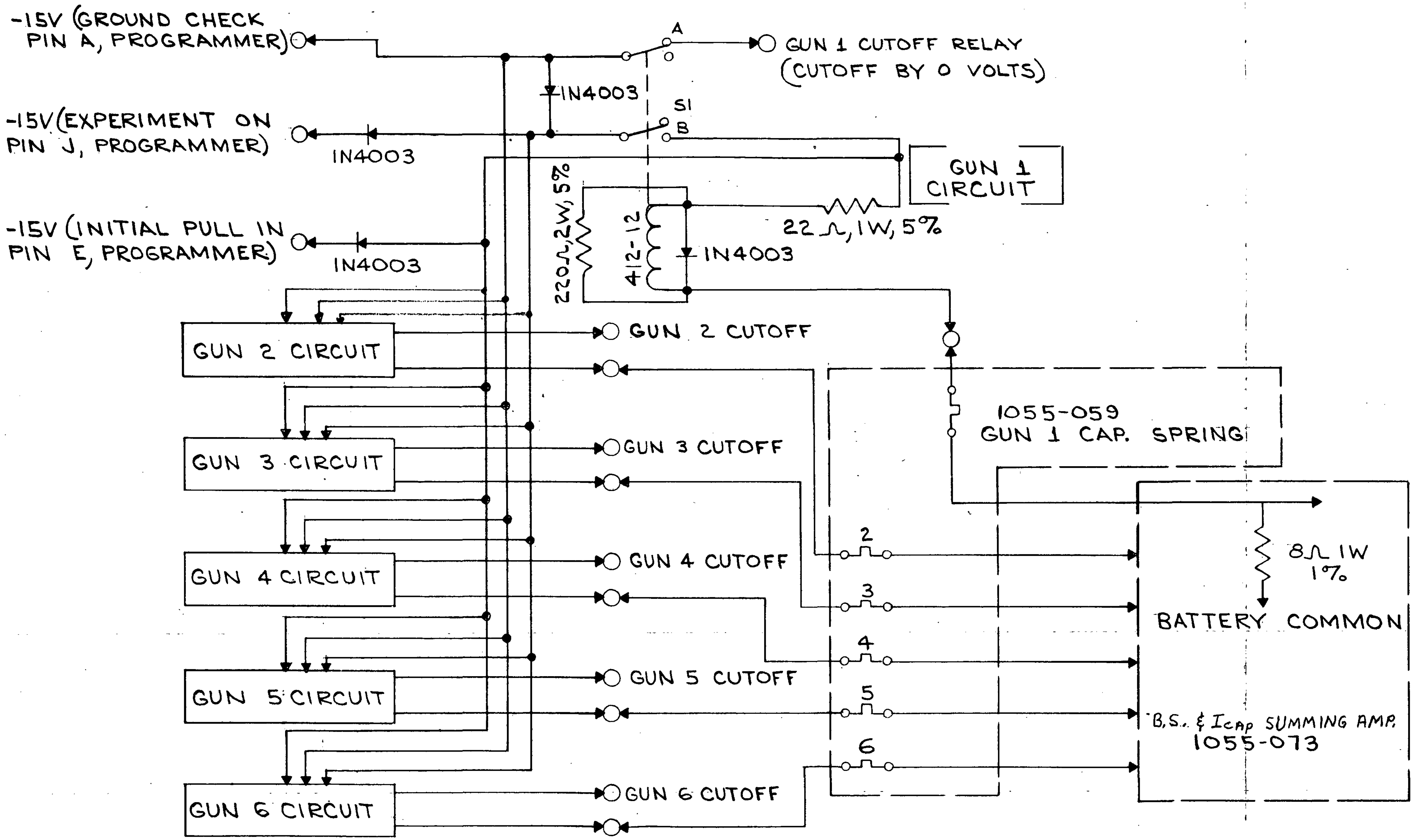


Figure 3-3. Gun Cutoff Breakseal Cap Current Monitor.

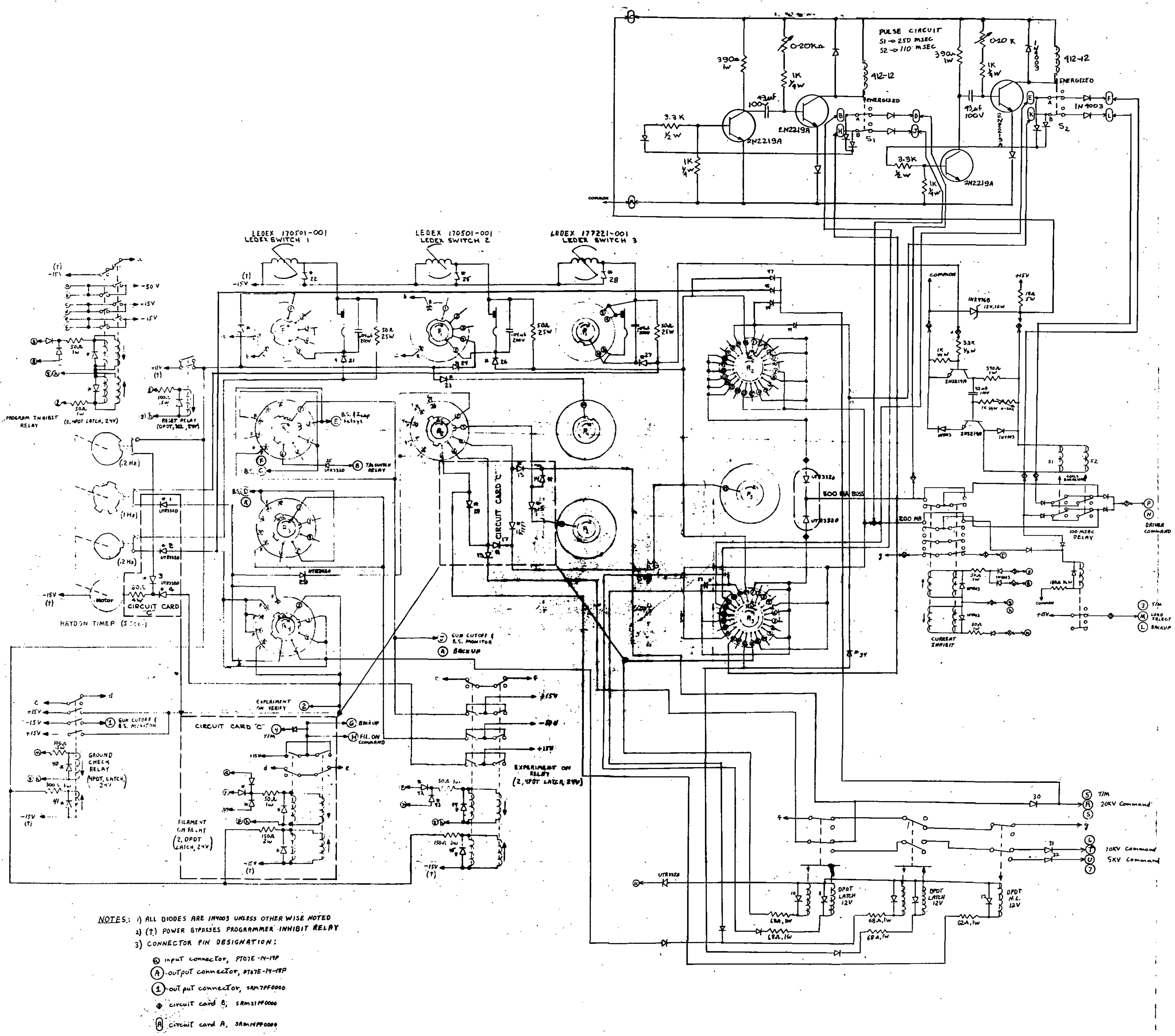


Figure 3-4. Programmer Schematic.

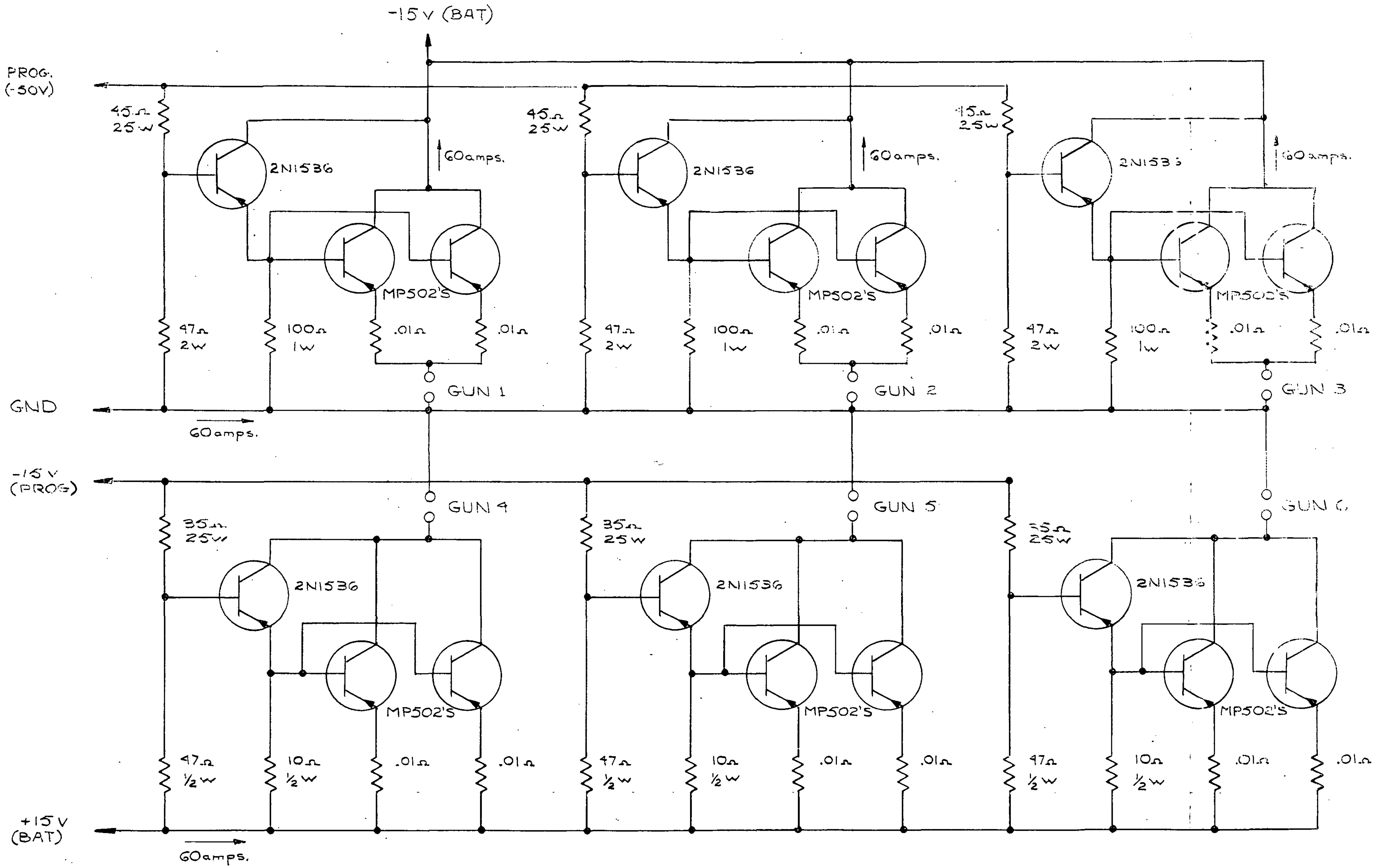


Figure 3-5. Break Seal Circuit.

SECTION 4

TELEMETRY, TELEMETRY CONDITIONS AND CALIBRATION

Figure 4-1 is a block diagram of the telemetry conditioning section, all control system functions were sensed with two independent monitors.

Table II is a list of the parameters monitored, how they were handled by the data link, which of the three links carried the parameter and on which subcarrier.

Figures 4-2 to 4-10 are the schematics of the monitor circuit shown in the block diagram of Figure 4-1.

For testing purposes prior to launch the positive battery, negative battery and cap current parameters were transmitted on a full time data link, during the flight, when the accelerator received a start command these parameters were switched by S1, S2 and S3, shown on Figure 4-1 to a commutated channel.

Figures 4-11 through 4-24 are the calibration curves for the accelerator/collector screen monitors.

TABLE II

Parameter After Channel Switch	Symbol	Link No.	Subcarrier	Band No.	Mode	Comm. Seq.	Other Names	Remarks
Beam Voltage #1	V_{B1}	3	52.5	17	Real Time	-	--	--
Beam Voltage #2	V_{B2}	2	22 KHz	14	Real Time	-	--	Link #2, freq. 244.3 MHz
Beam Current #1	I_{B1}	1	22 KHz	14	Real Time	-	--	--
Beam Current #2	I_{B2}	3	93 KHz	19	Real Time	-	--	--
Anode Current	I_A	3	70 KHz	18	Real Time	-	--	Link #3 freq. 239.4 MHz
Collector Current Group 4	I_{G4}	1	30 KHz	15	Real Time	-	I_{CRI} [Area 2, 3 & 4 front & rear]	Link #1 freq. 230.4 MHz
(Positive Battery)	$(+V_B)$	(1)	(30 KHz)	(15)	(Real Time)	-	--	Before channel switch
Collector Current Group 1	I_{G1}	3	165 KHz	21	Real Time	-	I_{CFO} [Area 1 & 5 front]	--
Collector Current Group 2	I_{G2}	3	124 KHz	20	Real Time	-	I_{CFI} [Area 1 & 5 rear]	--
(Cap Current & B.S)	(I_{CAPS})	3	124 KHz	20	Real Time	-	--	Before channel switch
Collector Current Group 3	I_{G3}	3	40 KHz	16	Real Time	-	I_{CRO} [Area 6, 7 & 8 front & rear]	--
(Negative Battery)	$(-V_B)$	3	40 KHz	16	Real Time	-	--	Before channel switch
Collector Current Total	I_C	1	40 KHz	16	Real Time	-	--	--
Positive Battery	$+V_B$	3	10.5 KHz	12	Comm.	3	--	--
Negative Battery	$-V_B$	3	10.5 KHz	12	Comm.	4	--	--
Cap Current B.S.	I_{CAP}	3	10.5 KHz	12	Comm.	5	--	--
Filament Current	I_{FIL}	3	10.5 KHz	12	Comm.	6	--	--
Package Pressure	P_{PP}	3	10.5 KHz	12	Comm.	7	--	--
Pos. Batt. Box Press.	P_{PB}	3	10.5 KHz	12	Comm.	8	--	--
Neg. Batt. Box Press.	P_{NB}	3	10.5 KHz	12	Comm.	9	--	--
Pos. Battery Temp.	T_P	3	10.5 KHz	12	Comm.	-	--	--
Neg. Battery Temp.	T_N	3	10.5 KHz	12	Comm.	11	--	--
Accel. Package Temp.	T_{AP}	3	10.5 KHz	12	Comm.	10	--	--
Heat Sink Temperature	T_{HS}	3	10.5 KHz	12	Comm.	-	--	--
20 kV Comm. Monitor	-	3	10.5 KHz	12	Comm.	-	--	--
10 kV Comm. Monitor	-	3	10.5 KHz	12	Comm.	-	--	--
Fil "on" Monitor	-	3	10.5 KHz	12	Comm.	12	--	--
500 mA Comm. Monitor	-	3	10.5 KHz	12	Comm.	14	--	--
20 kV Output Monitor	-	3	10.5 KHz	12	Comm.	15	--	--
Experiment "on" Monitor	-	3	10.5 KHz	12	Comm.	13	--	--

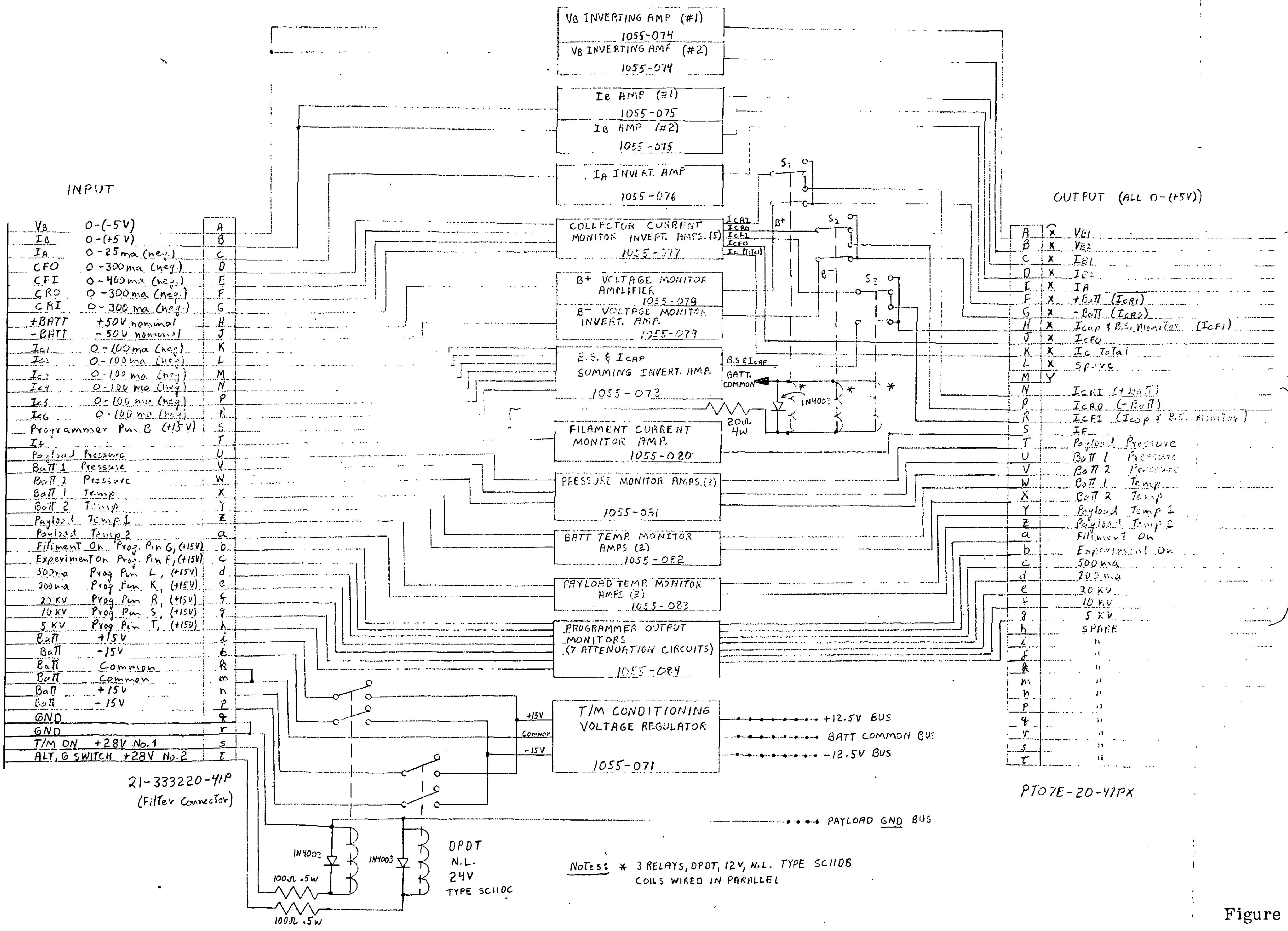
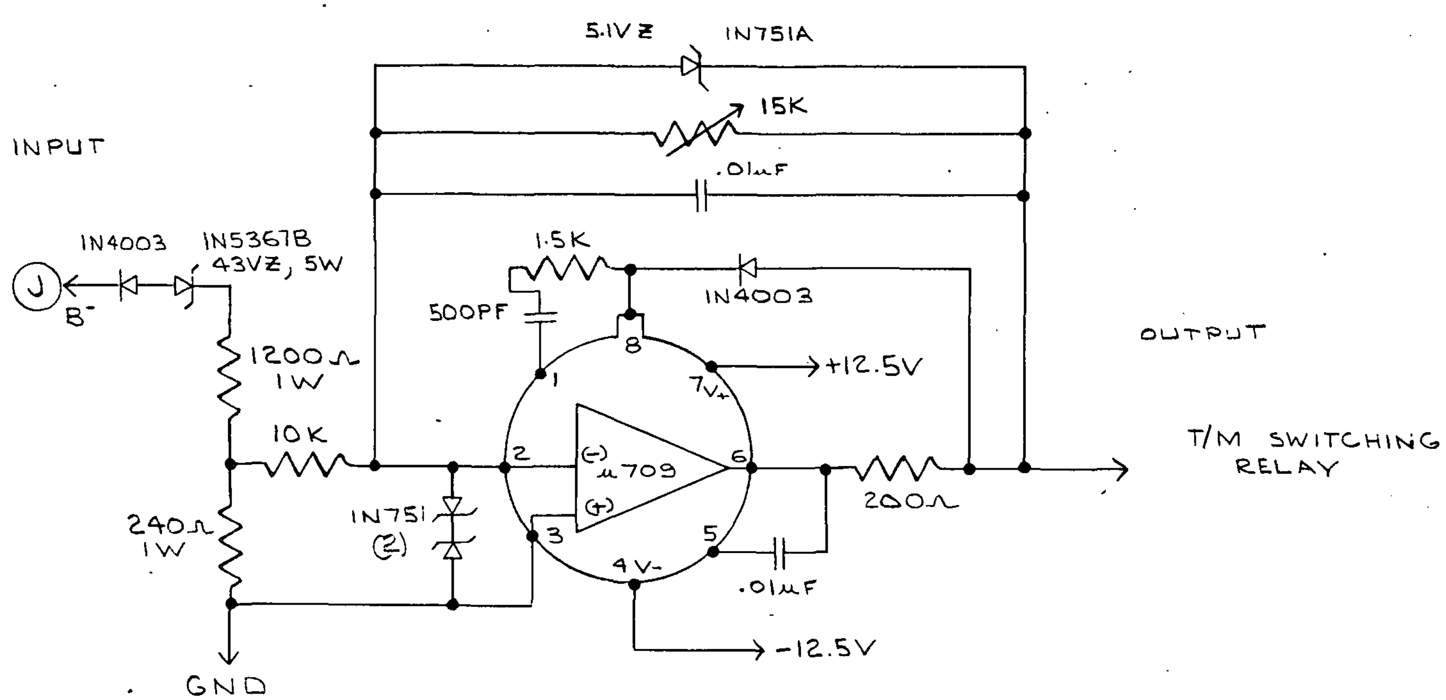


Figure 4-1. T/M Conditioning Schematic.

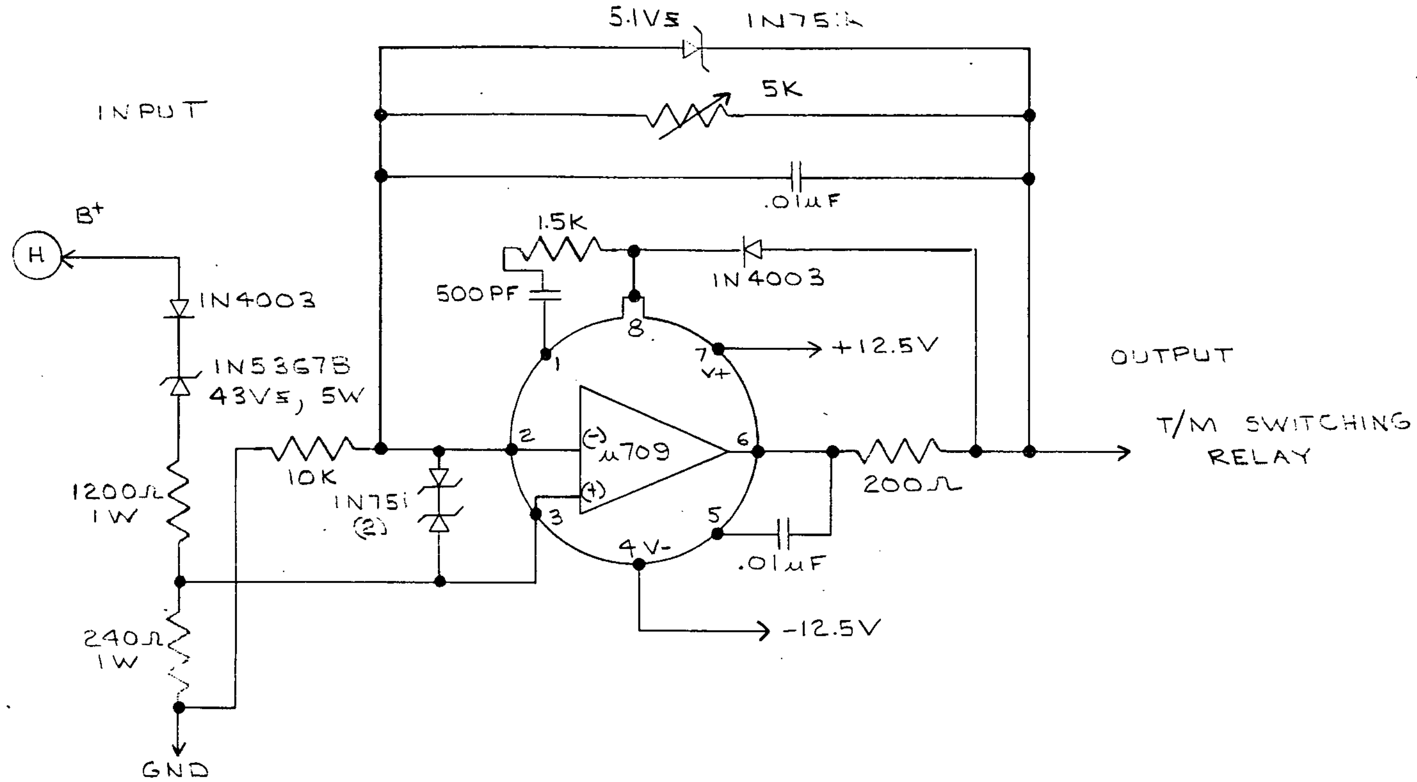


NOTES:

1) ALL RESISTORS ¼ W CARBON 5% UNLESS OTHERWISE STATED.

2) ADJUST SUCH THAT -68V INPUT GIVES +5V OUTPUT. [B⁻ = -43V-(5V OUT)]

Figure 4-2. B⁻ Voltage Monitor.

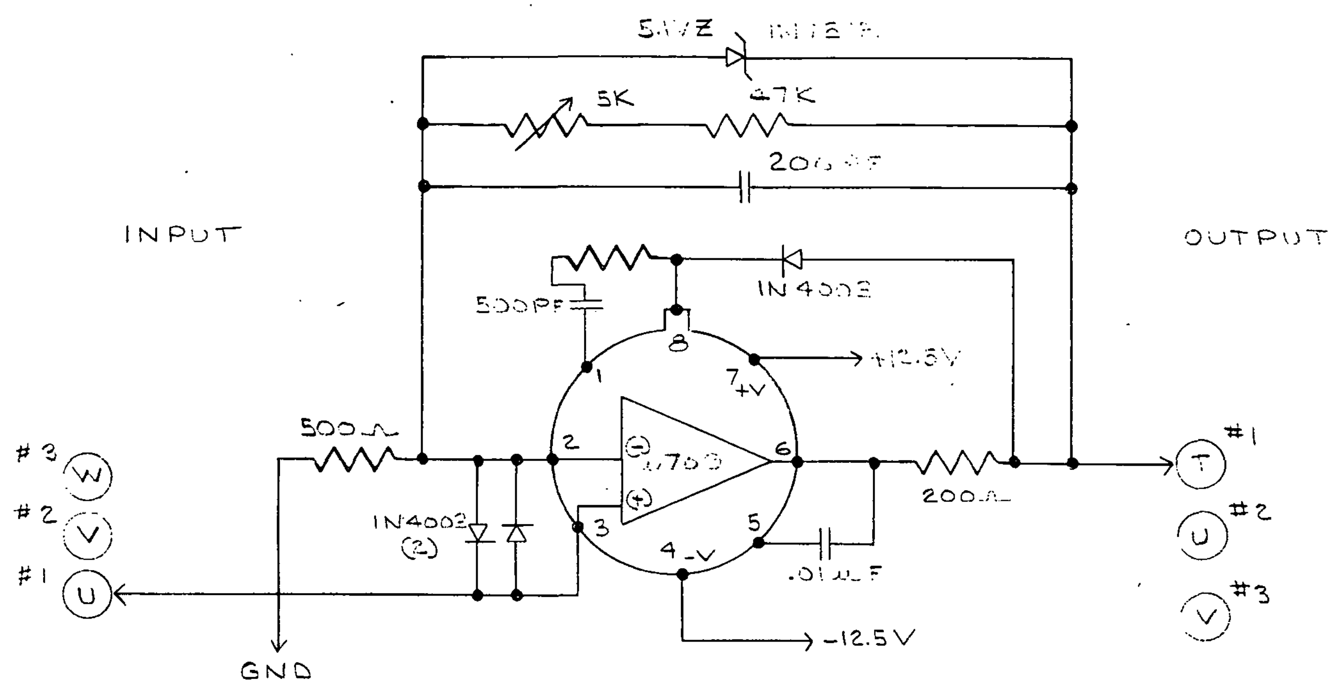


NOTES:

1) ALL RESISTORS ¼ W CARBON 5% UNLESS OTHERWISE NOTED.

2) ADJUST SUCH THAT +68V INPUT GIVES +5V OUTPUT. [B+ = 43V + 5(V OUT)]

Figure 4-3. B^+ Voltage Monitor.

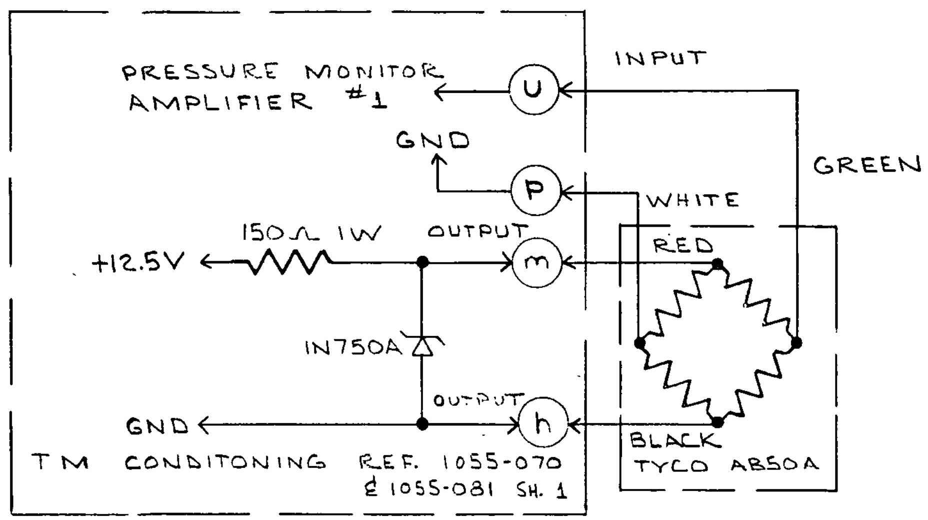


NOTES:

1) ALL RESISTORS ¼W CARBON 5% UNLESS OTHERWISE NOTED.

2) 3 SUCH CIRCUITS USED, TO BE ADJUSTED AS FOLLOWS:
#1 PAYLOOD PRESSURE: 70MV IN GIVES 5V OUT
#2 BATTERY 1: 50MV IN GIVES 5V OUT
#3 BATTERY 2: 50MV IN GIVES 5V OUT

Figure 4-4. Pressure Monitor Amplifier.



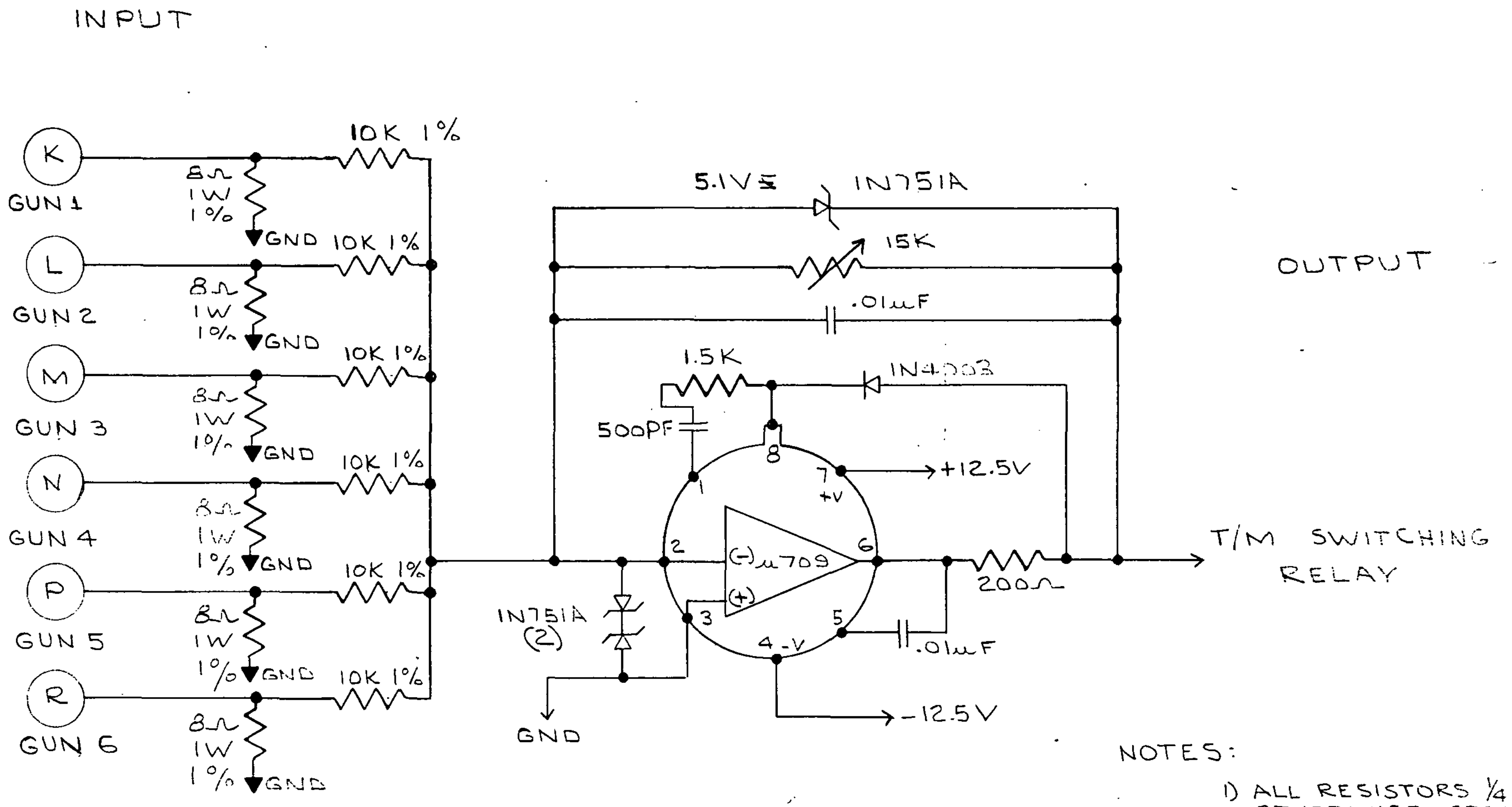
NOTES:

1). TRANSDUCER IS MOUNTED IN PAYLOAD PRESSURE CANISTER.

2) CHECK WORK ABILITY OF OUTPUT GROUND RETURN. CAN THIS BE DIRECTLY CONNECTED TO BATT. COMMON BUS?

Not a Final Drawing

Figure 4-5. Payload Pressure Transducer.

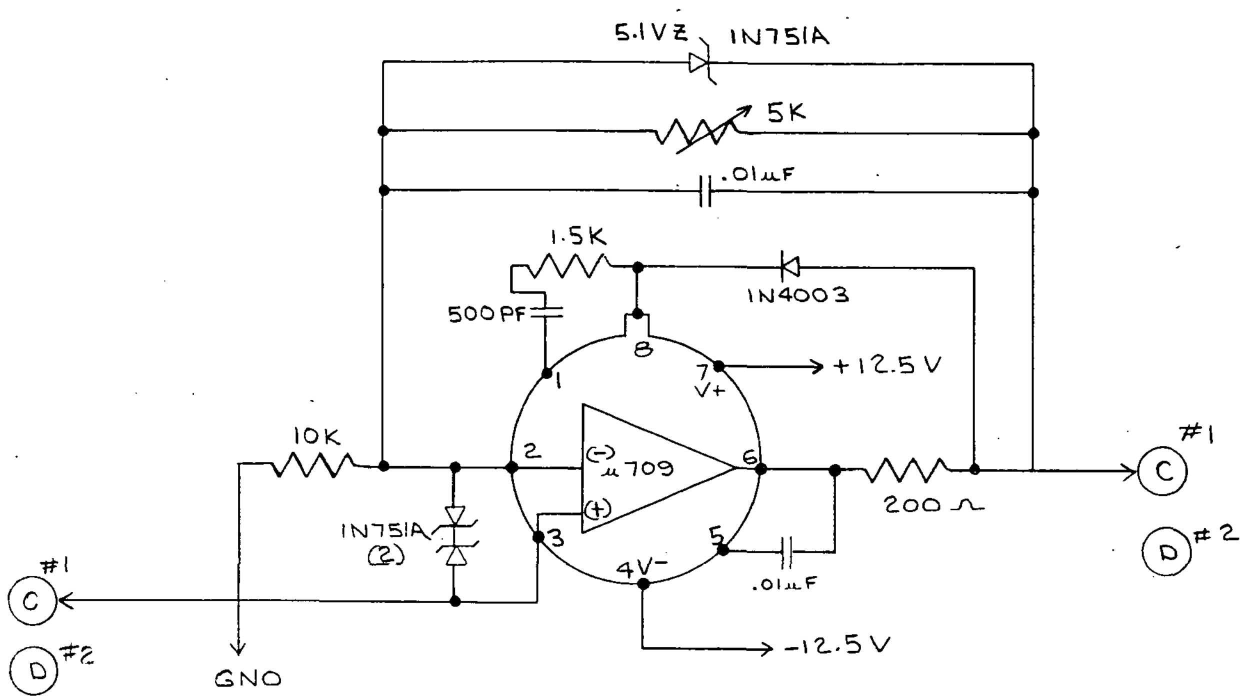


NOTES:

1) ALL RESISTORS ¼W CARBON 5% UNLESS OTHERWISE SPECIFIED.

2) ADJUST SUCH THAT 100 MA AT EACH INPUT GIVES 5V OUTPUT.

Figure 4-6. B.S. I_{CAP} Summing Amplifier.



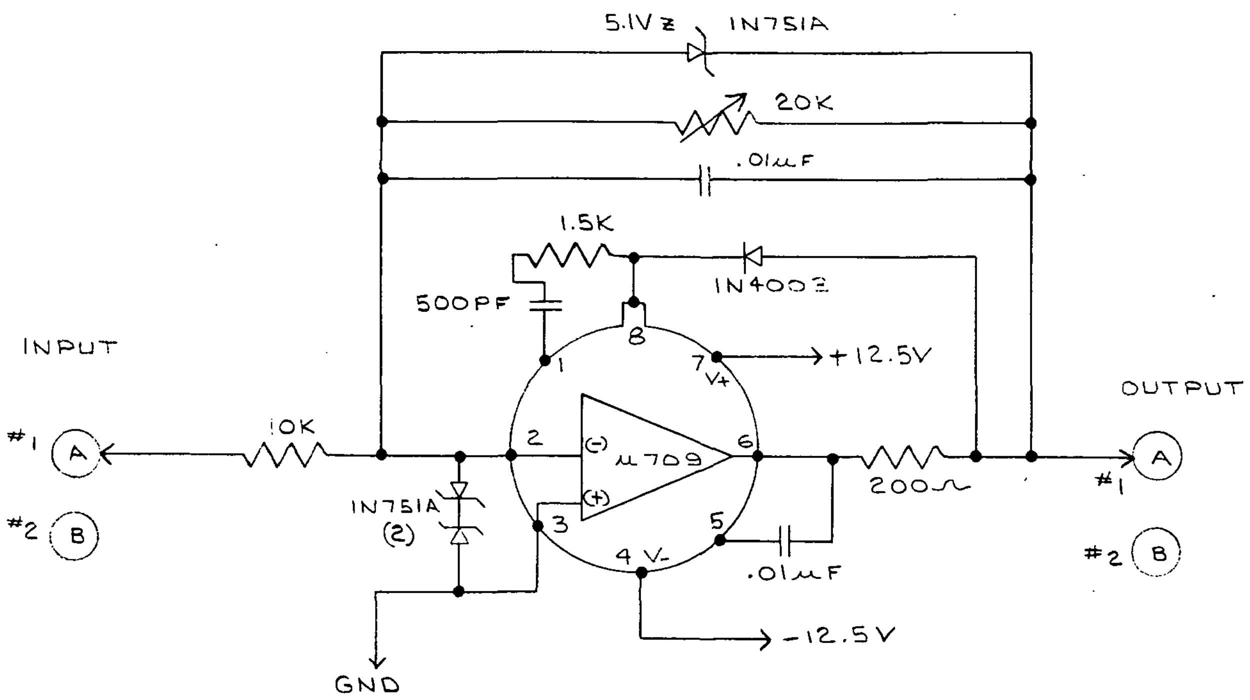
NOTES:

1) ALL RESISTORS ¼ W CARBON 5% UNLESS OTHERWISE NOTED.

2) TWO OF THESE CIRCUITS ARE USED EACH WITH INDEPENDENT INPUT & OUTPUT.

3) ADJUST SUCH THAT 500 MA BEAM CURRENT GIVES 5V OUTPUT.

Figure 4-7. Beam Current Monitor.



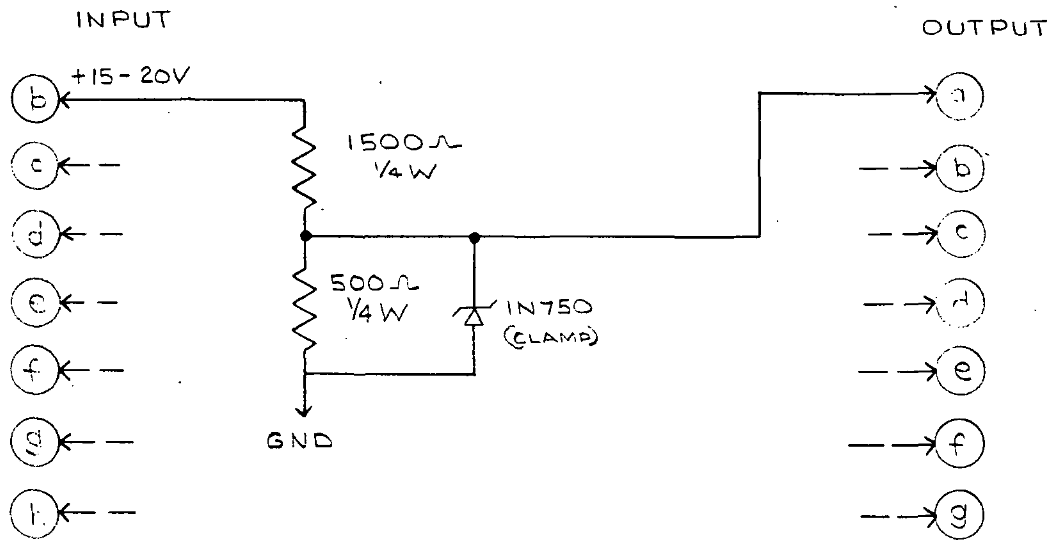
NOTES:

1) ALL RESISTORS ¼ W CARBON 5% UNLESS OTHERWISE STATED.

2) TWO OF THESE CIRCUITS ARE USED EACH WITH INDEPENDENT INPUT & OUTPUT.

3. ADJUST SUCH THAT FULL CONVETER OCV (≈ 30KV) GIVES +5V OUTPUT.

Figure 4-8. Beam Voltage Inverting Amplifier (#1 and #2).



NOTES:

1) SEVEN IDENTICAL CIRCUITS WITH SEPERATE INPUT & OUTPUT. REF. 1055-070

Figure 4-9. Programmer Output Monitor.

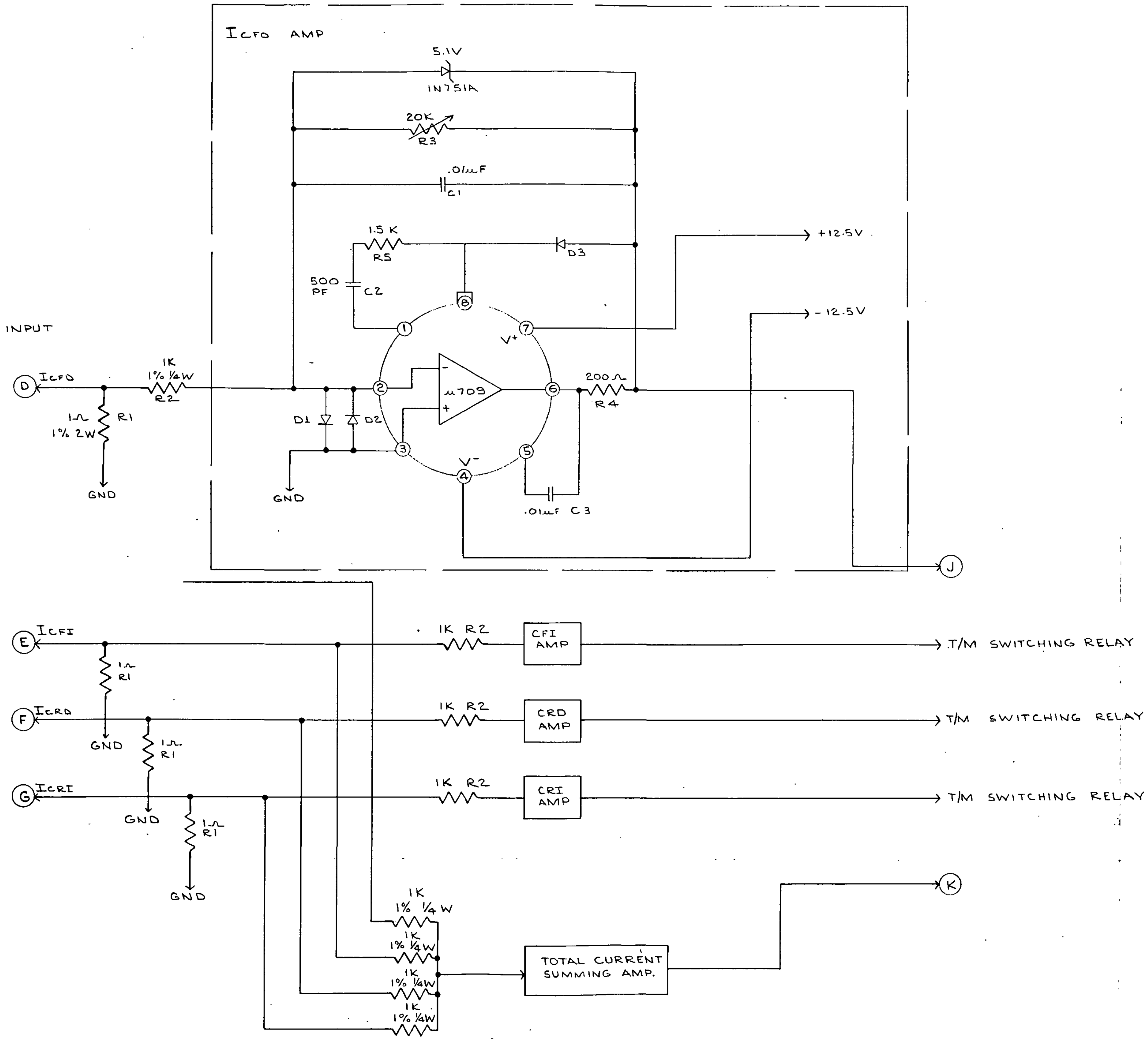


Figure 4-10. Collector Current Monitor OP. Amp Circuits.

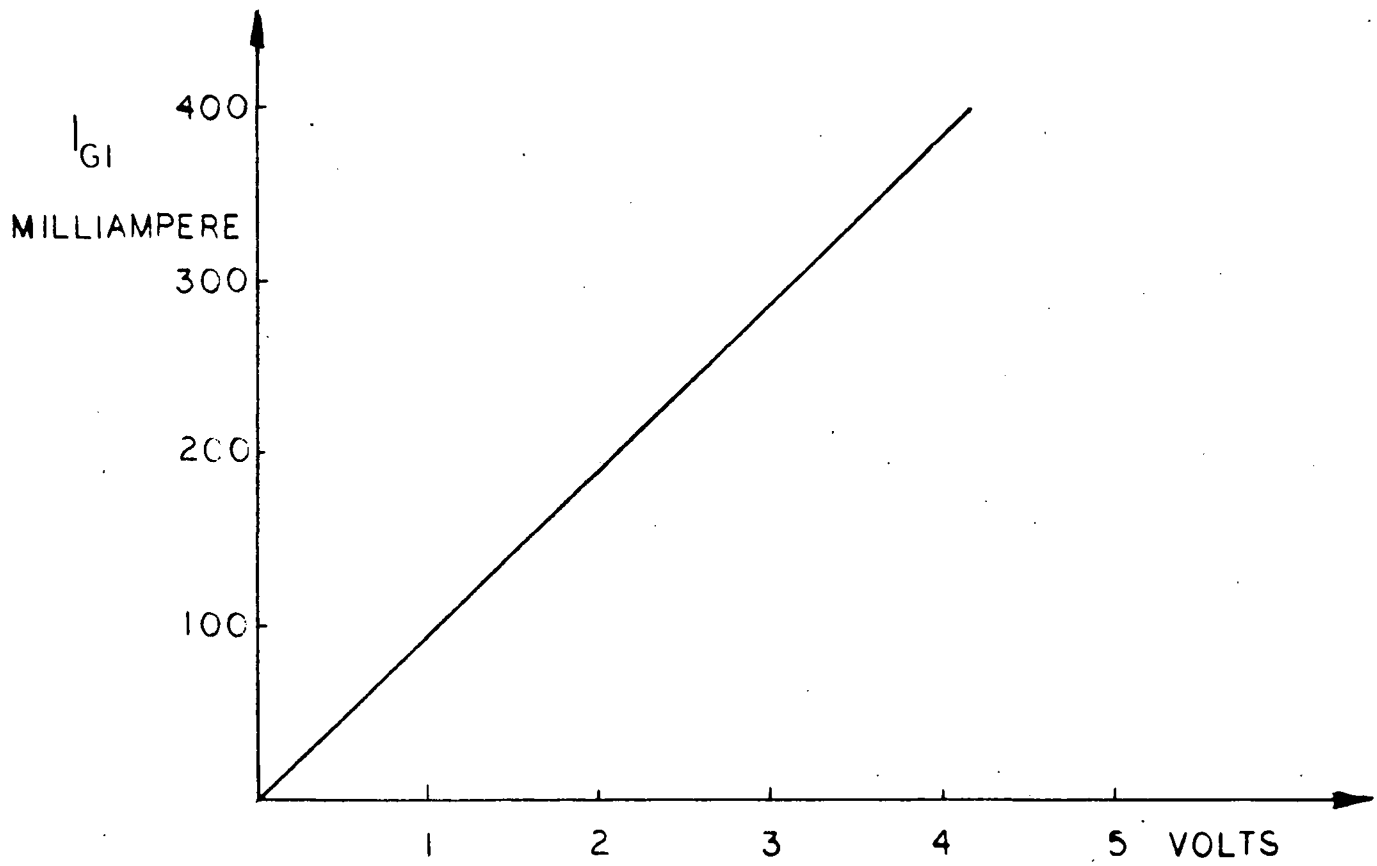


Figure 4-11. Collector Current Group #1 (I_{G1}).

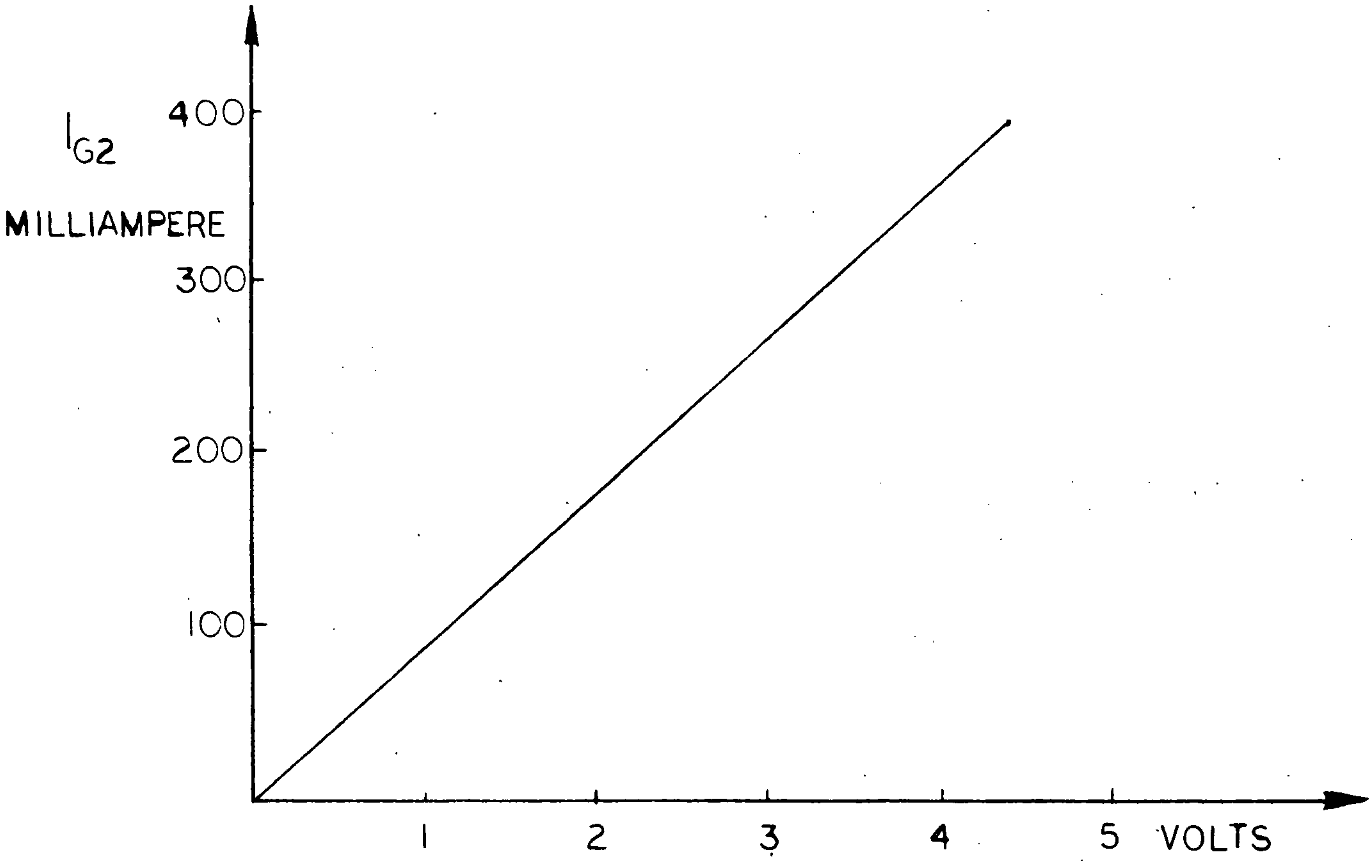


Figure 4-12. Collector Current Group #2 (I_{G2}).

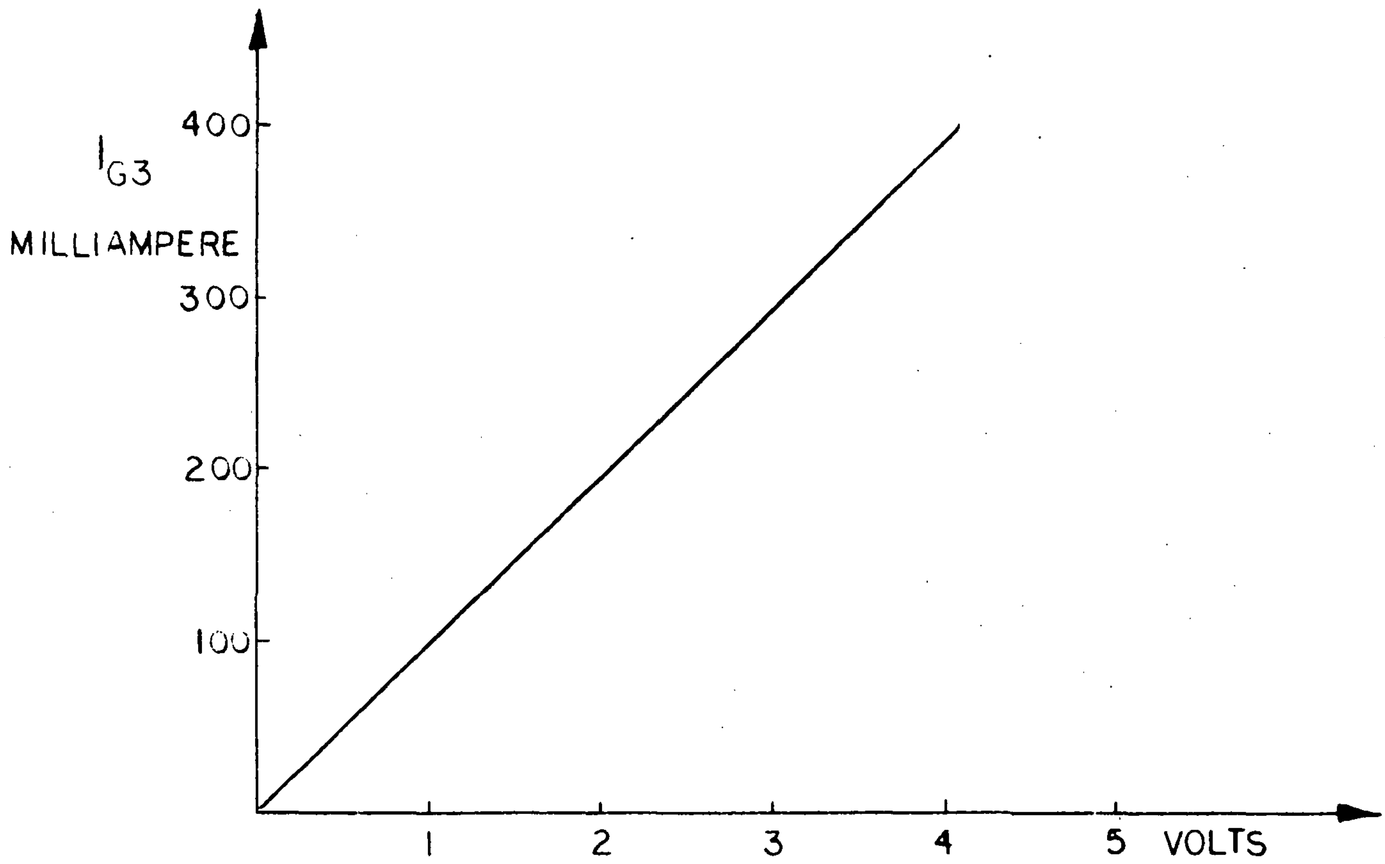


Figure 4-13. Collector Current Group #3 (I_{G3}).

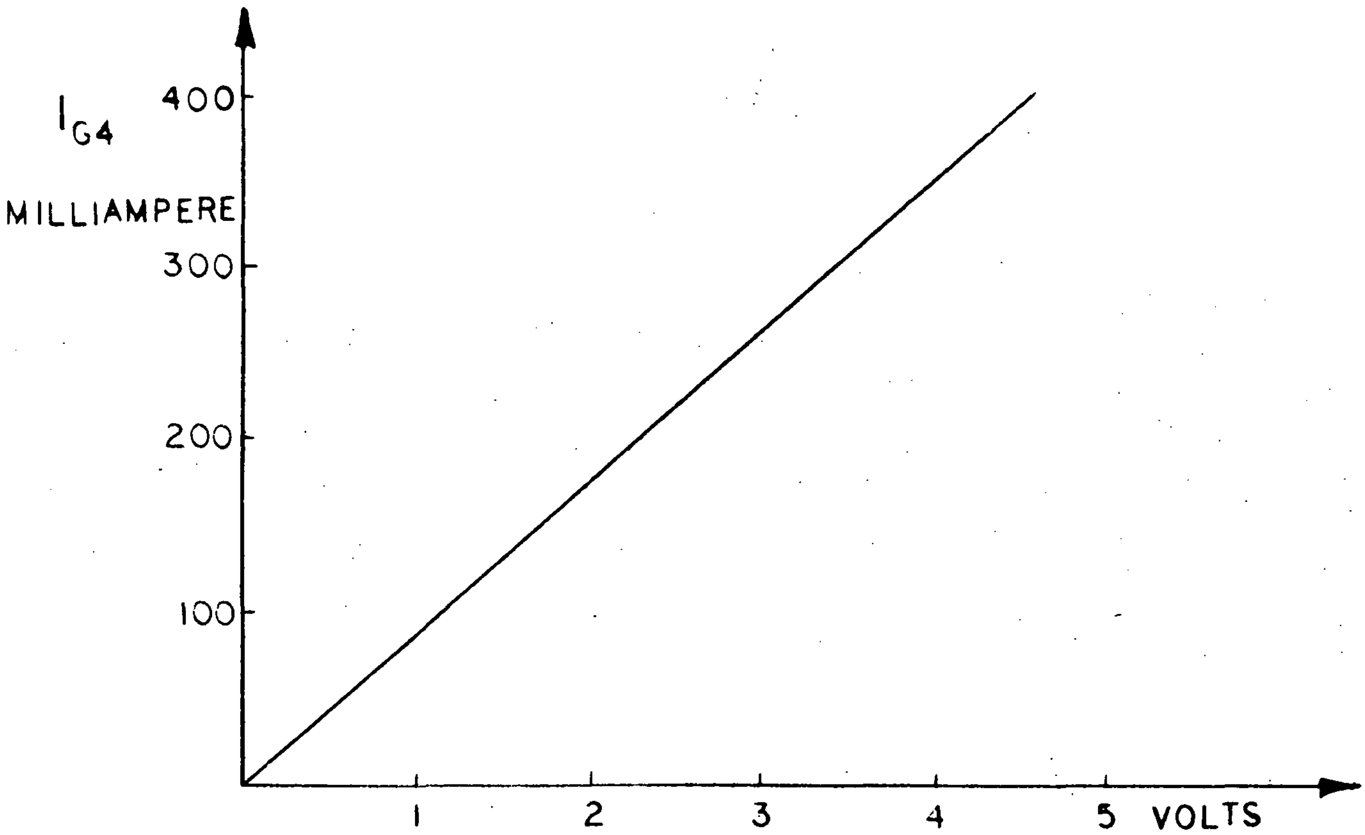


Figure 4-14. Collector Current Group #4 (I_{G4}).

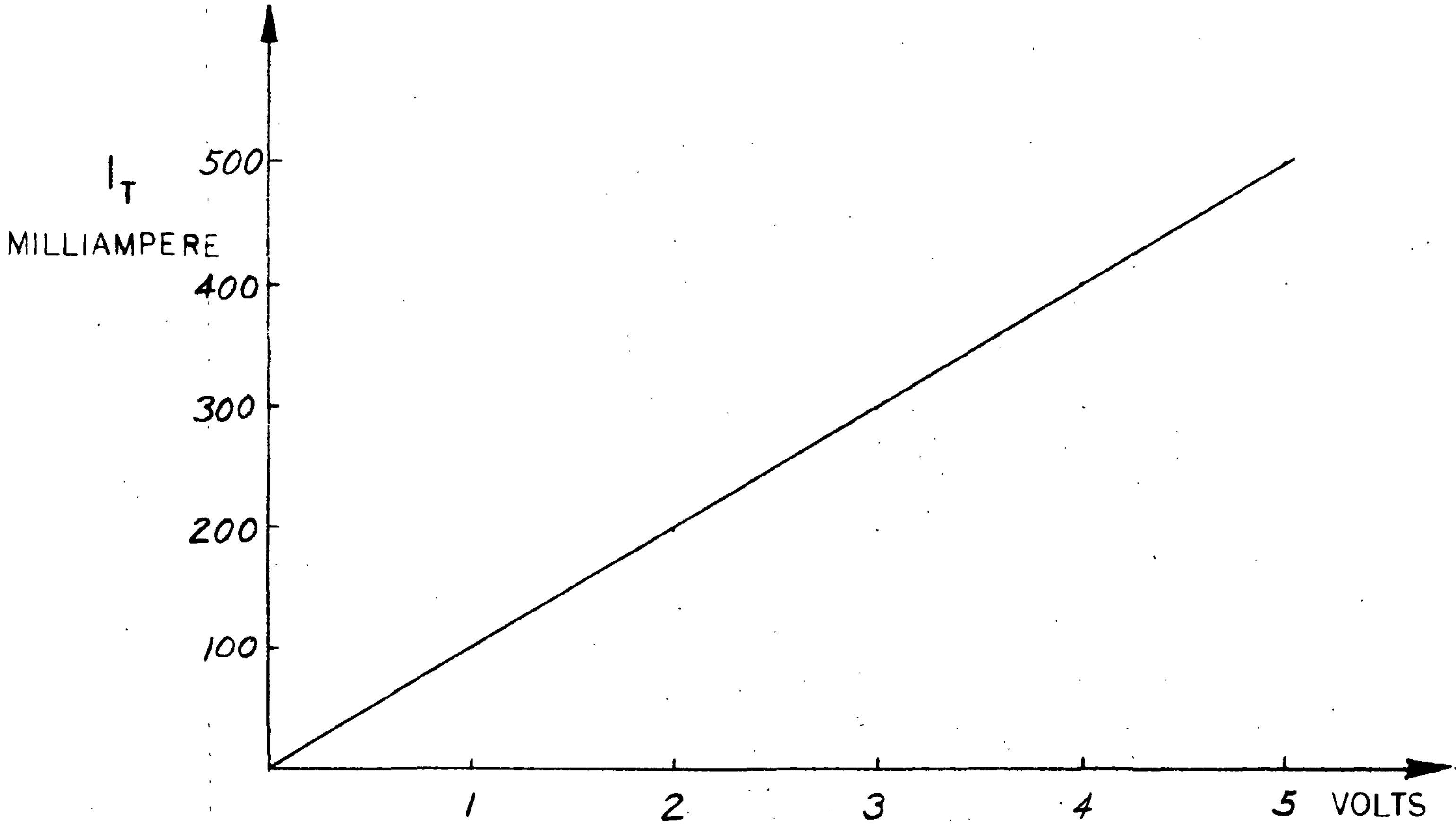


Figure 4-15. Total Collector Current (I_T).

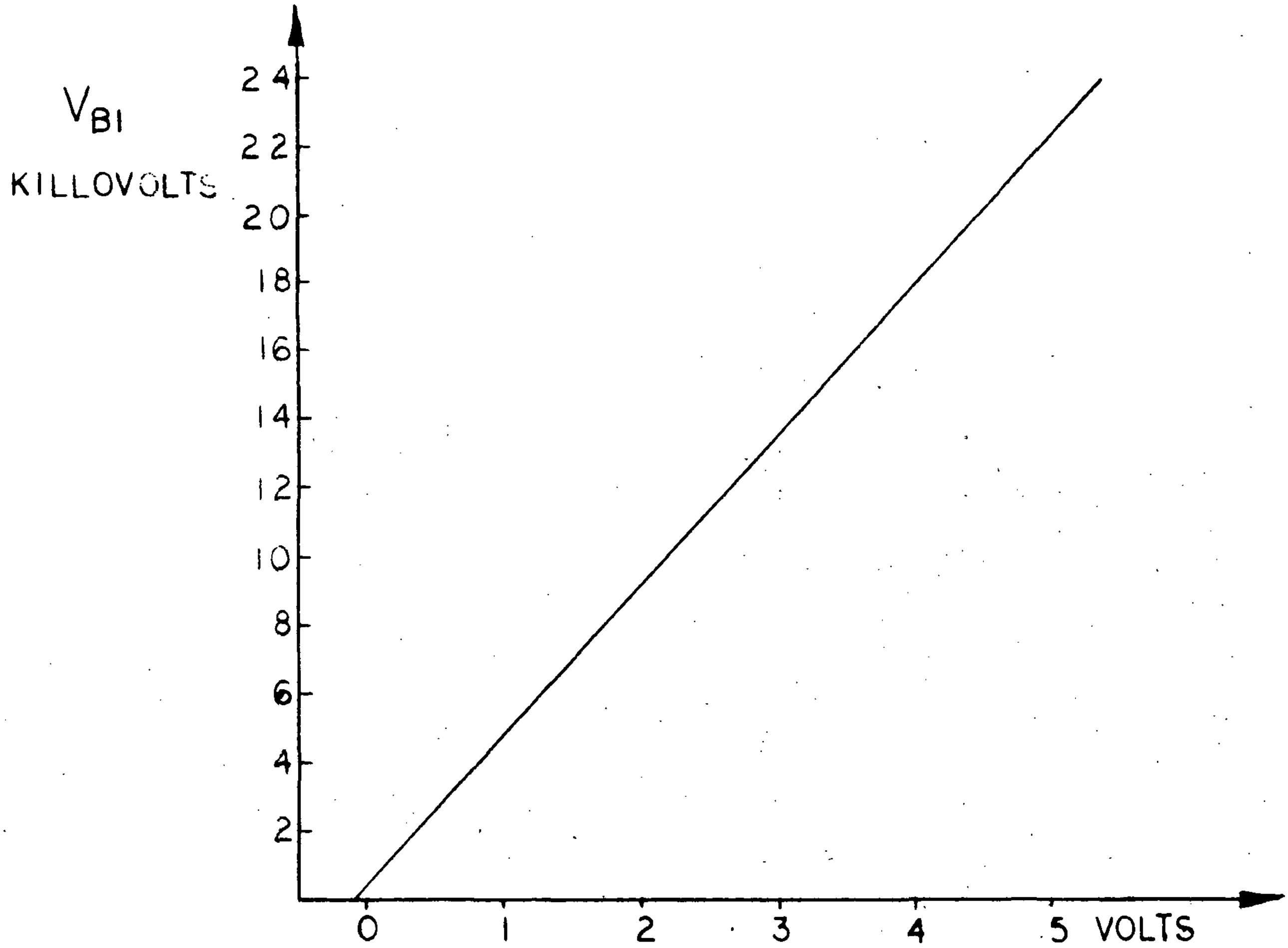


Figure 4-16. Number One Beam Voltage Monitor (V_{B1}).

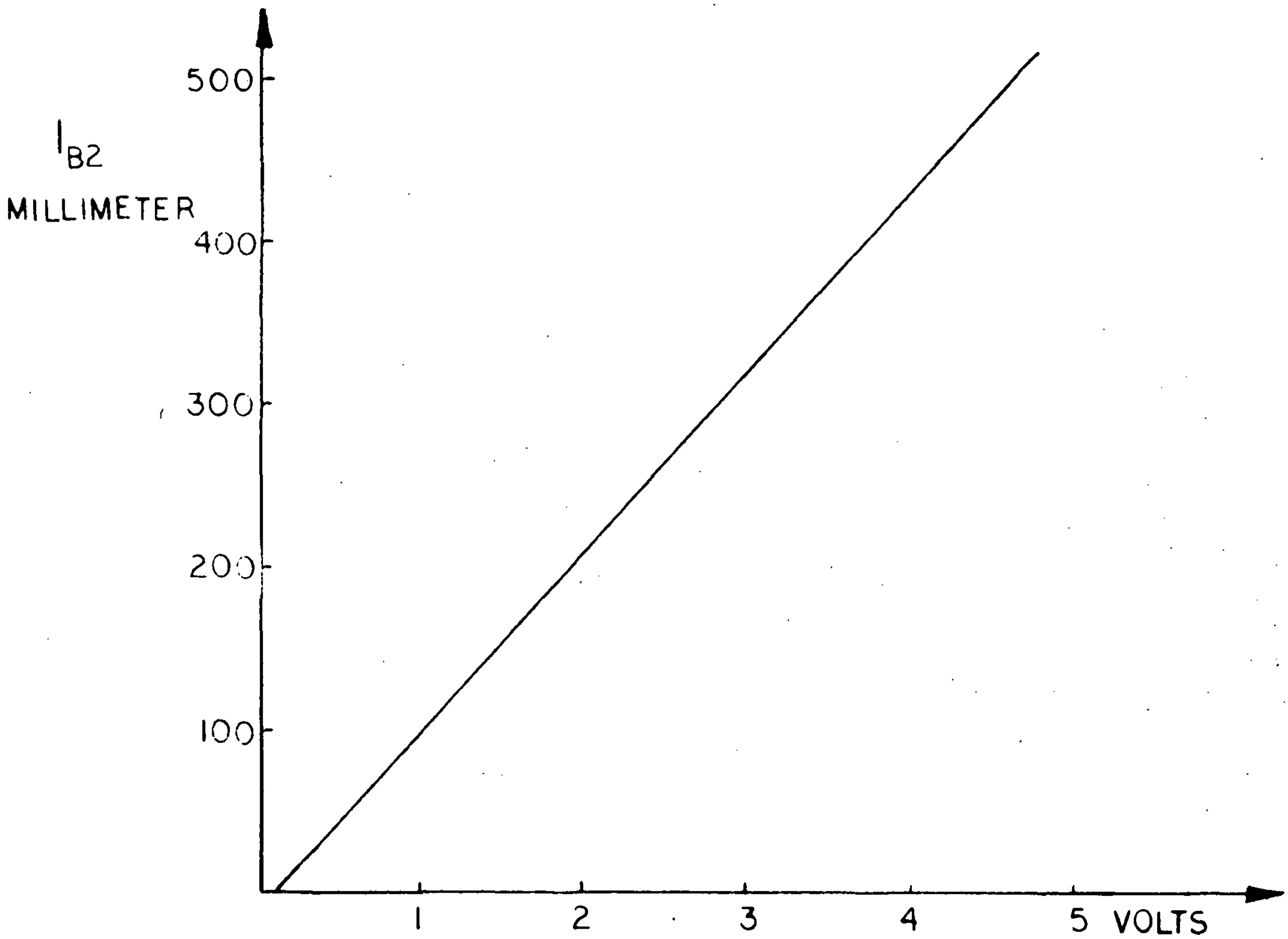


Figure 4-17. Number Two Beam Current Monitor (I_{B2}).

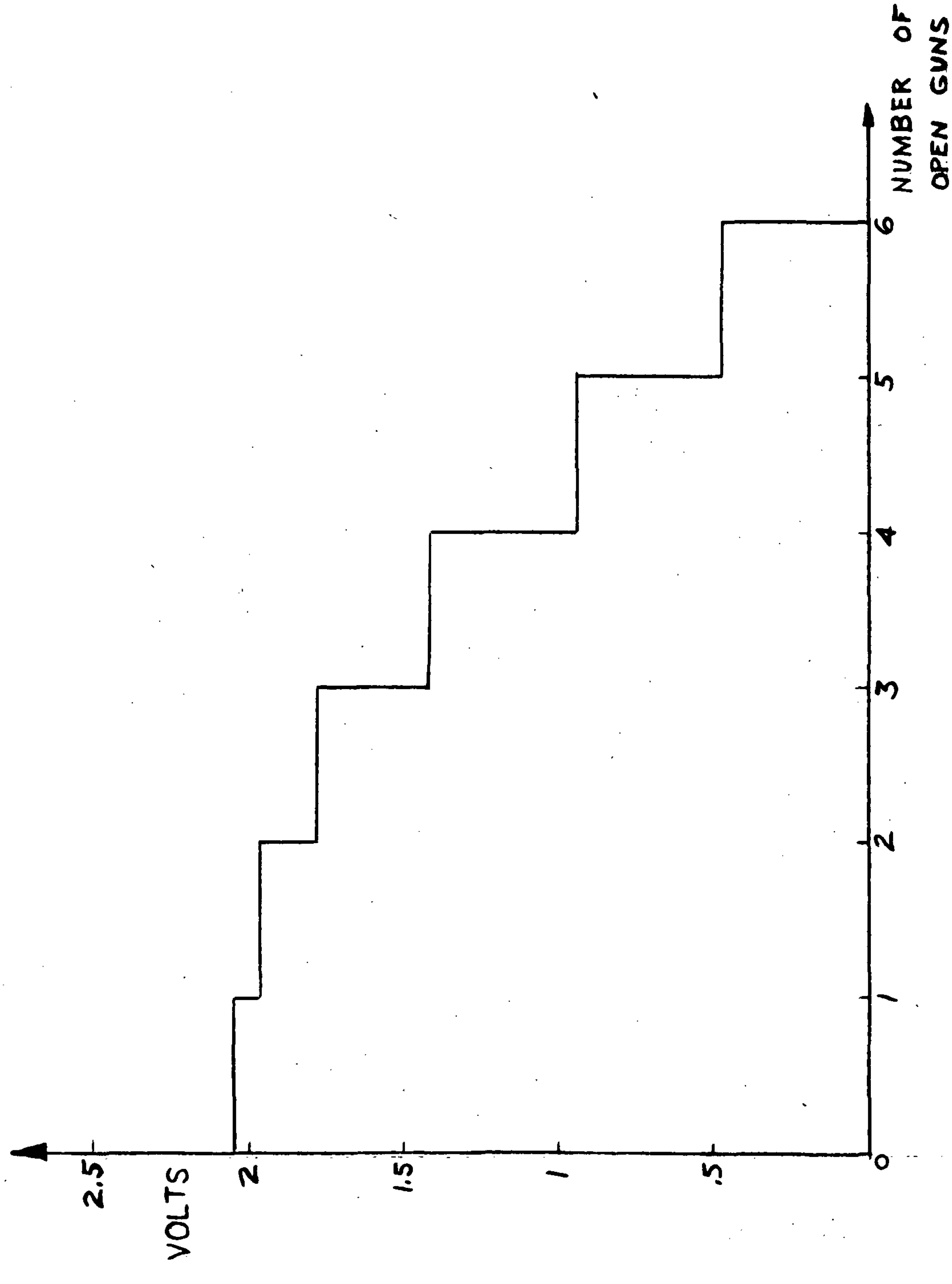


Figure 4-18. Gun Opening Monitor.

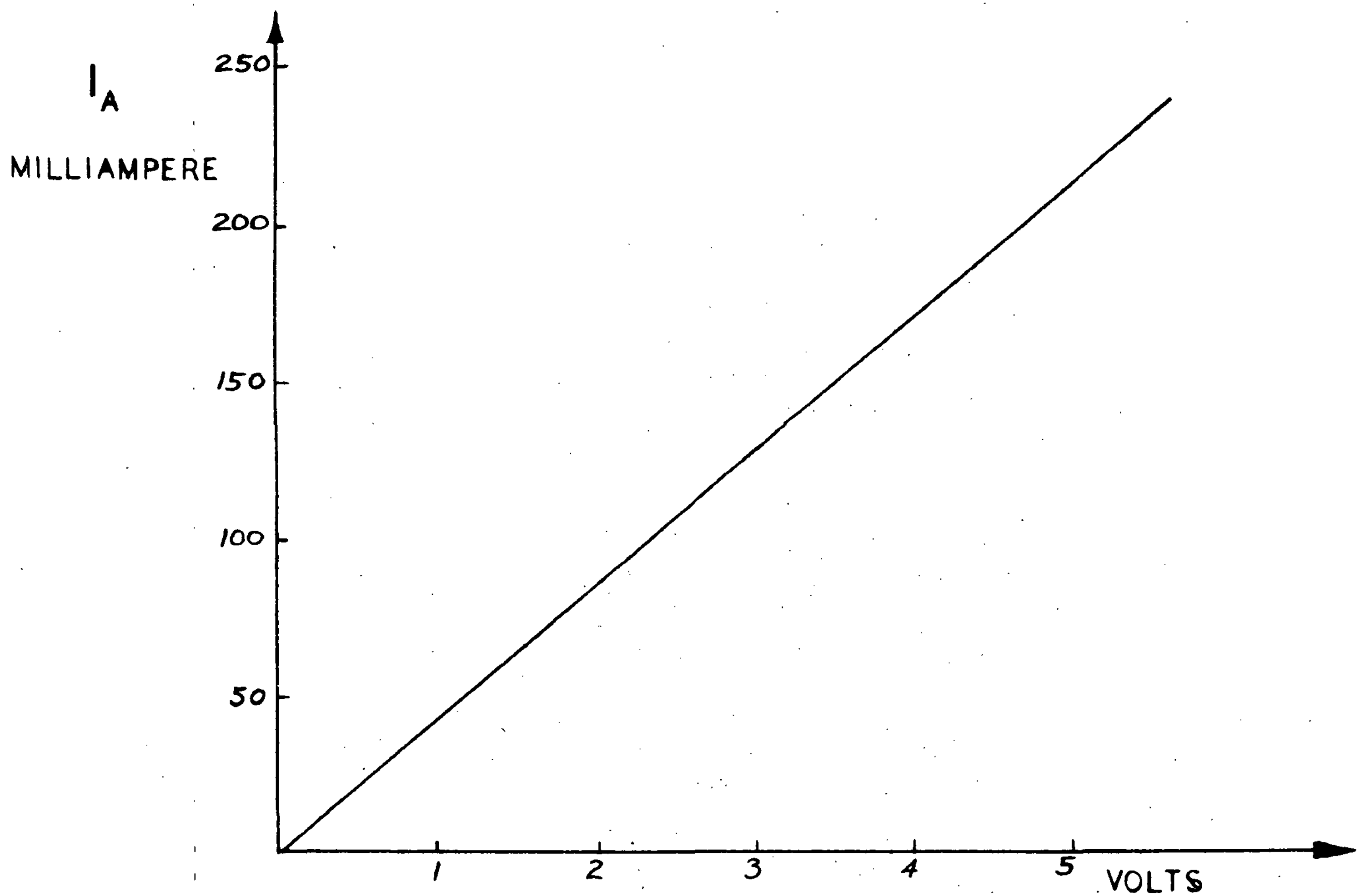


Figure 4-19. Anode Current (I_A).

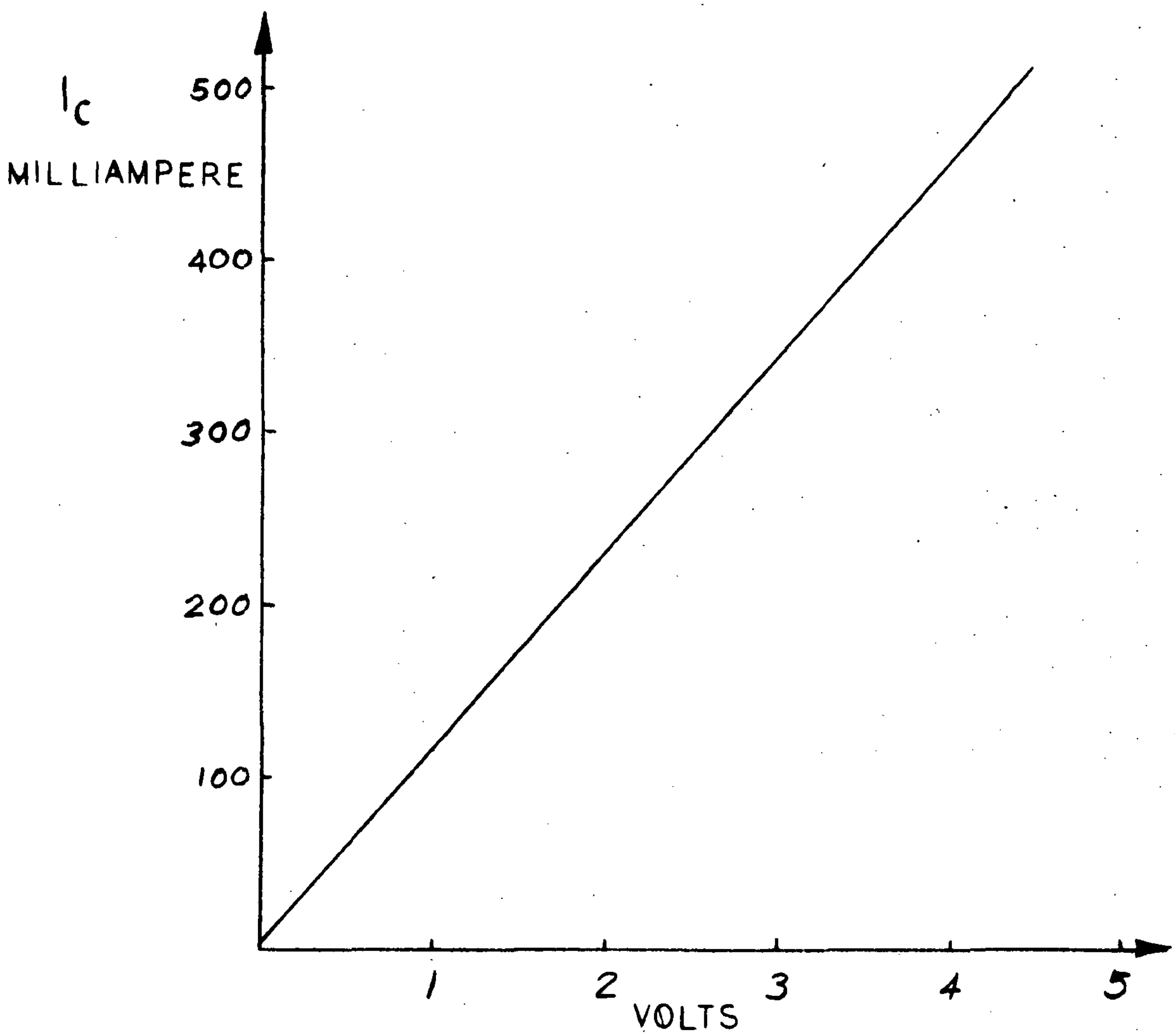


Figure 4-20. Gun Cap Current (I_C).

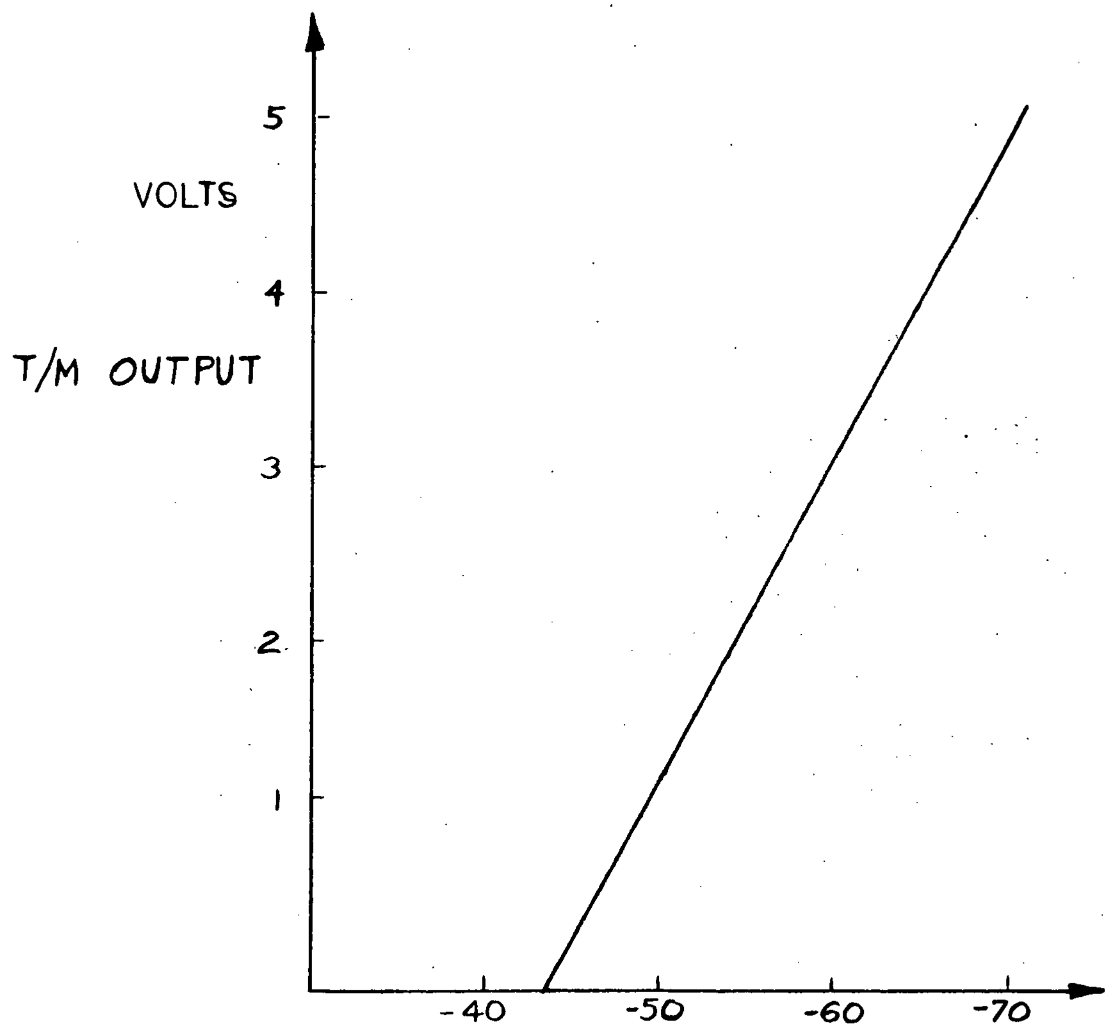


Figure 4-21. Battery Voltage Negative.

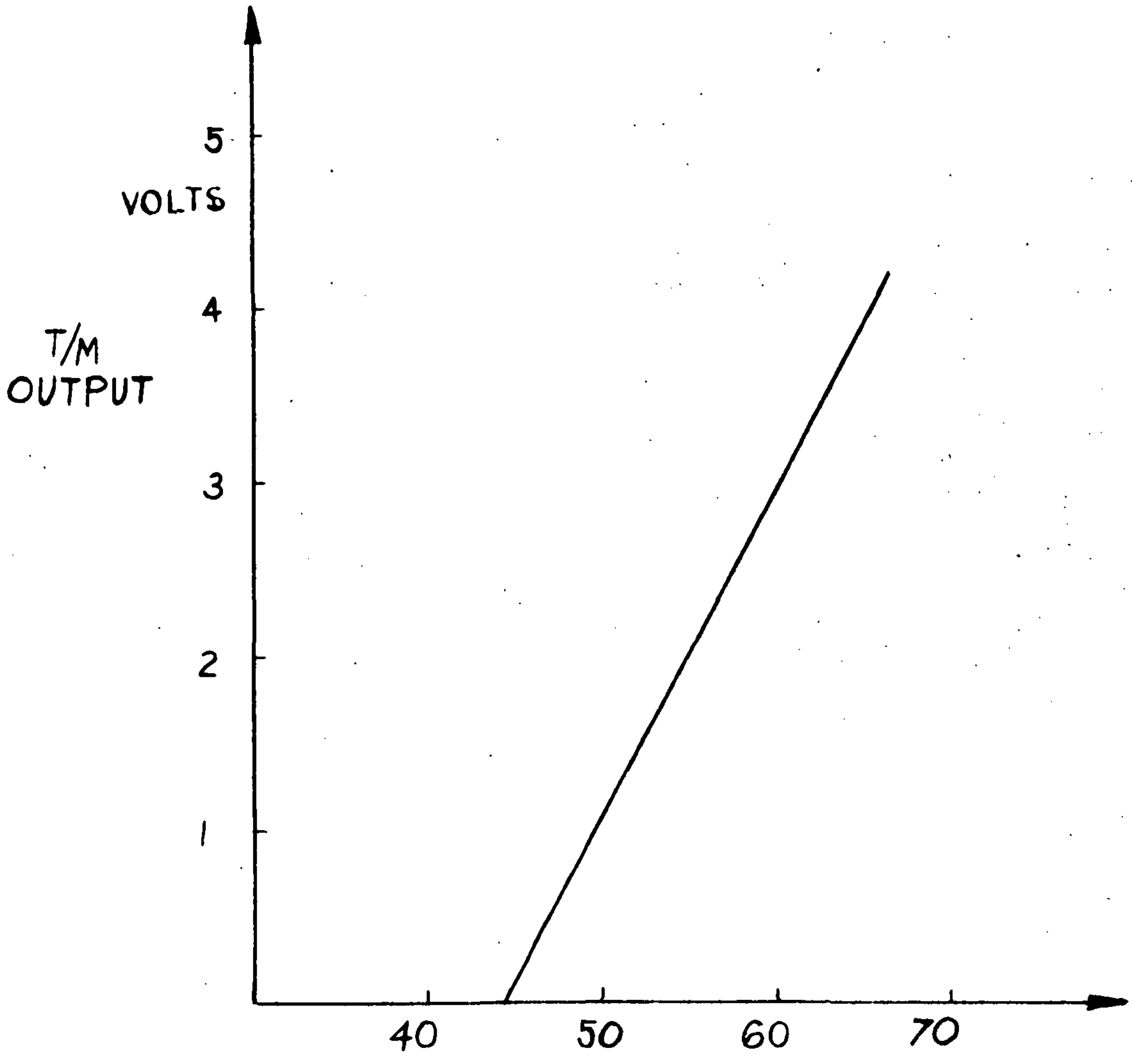


Figure 4-22. Battery Voltage Positive.

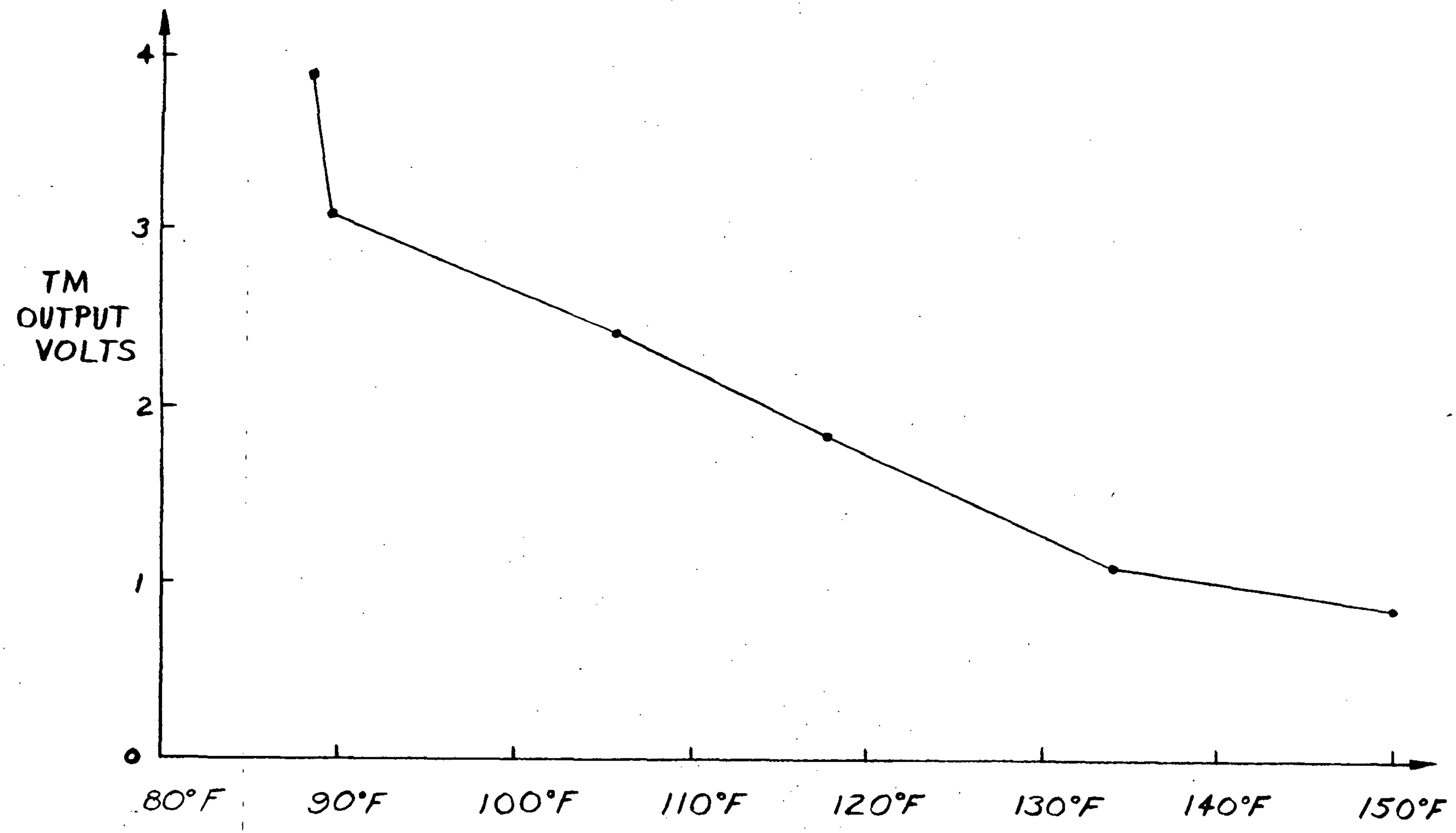


Figure 4-23. Payload Temperature.

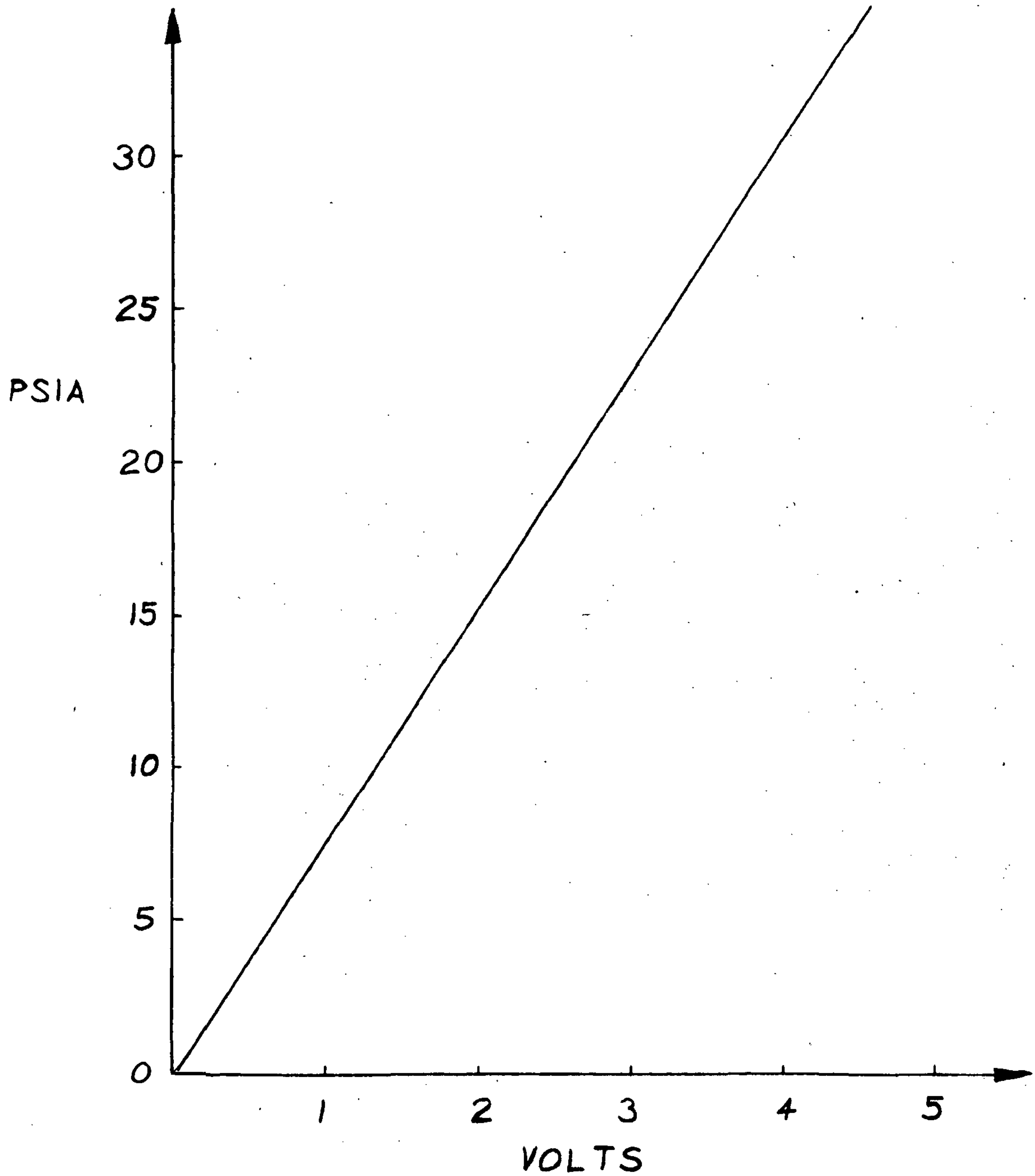


Figure 4-24. Package Pressure.

SECTION 5
POWER CONVERSION

The accelerating voltage required for system operation is provided by twenty 1 kilovolt converter modules connected in series.

5.1 Subsystem General Characteristics

The basic subsystem power supply is designed to provide from 0 to 500 mA current at 5 kV, 10 kV and 20 kV nominal voltage, depending upon the logic signal from the programmer.

The power producing elements are housed in a separate section of the payload. Battery inputs, turn-on signals and certain T/M functions are passed through a massive aluminum bulkhead on the side of the payload which serves as a ground bus. The converter is mounted into the lower half of the pressurized cannister as can be seen in Figure 1-1.

The basic electrical design consists of 20 individually driven bridge converter modules, each capable of supplying 1.0 kV at 500 mA. Isolation on the high voltage sections of each converter for half of the modules was tested to 30 kV. The outputs of all 20 converters are connected in series. Turn-on of each module is controlled by a small relay in the drive oscillator stage of each module.

5.2 Circuit Operation

Circuit operation is quite straightforward. The gating signals come from the experiment programmer where they turn on the appropriate number of high voltage modules by means of the relays positioned in the oscillator modules.

The main power circuit is in the form of a driven bridge inverter feeding the h.v. transformer. Adequate drive power is provided to the bridge Q_3 - Q_6. There are two transistors per arm of the bridge. To further protect against h.v. breakdowns and other transients, the h.v. transformer is carefully electrostatically shielded between primary and secondary. In addition zeners CR 15-18 directly protect bridge transistors against surges which pass the transformers. The power transformer is operated unsaturated.

Typical load regulation of a module is given in Figure 5-3. Line regulation is equal to battery regulation over the useable range of battery voltage and current loadings. It can be seen in Figure 5-3 that the short circuit protection operates effectively above about 550 mA output, dropping the output voltage to a low value below 100 volts. This type of protection, however, does not turn the unit off.

At plus and minus 50 V input and no load the unit input draws about 0.5 amp. Fully loaded to 500 mA, the overall power efficiency including oscillator and driver stages is 71%.

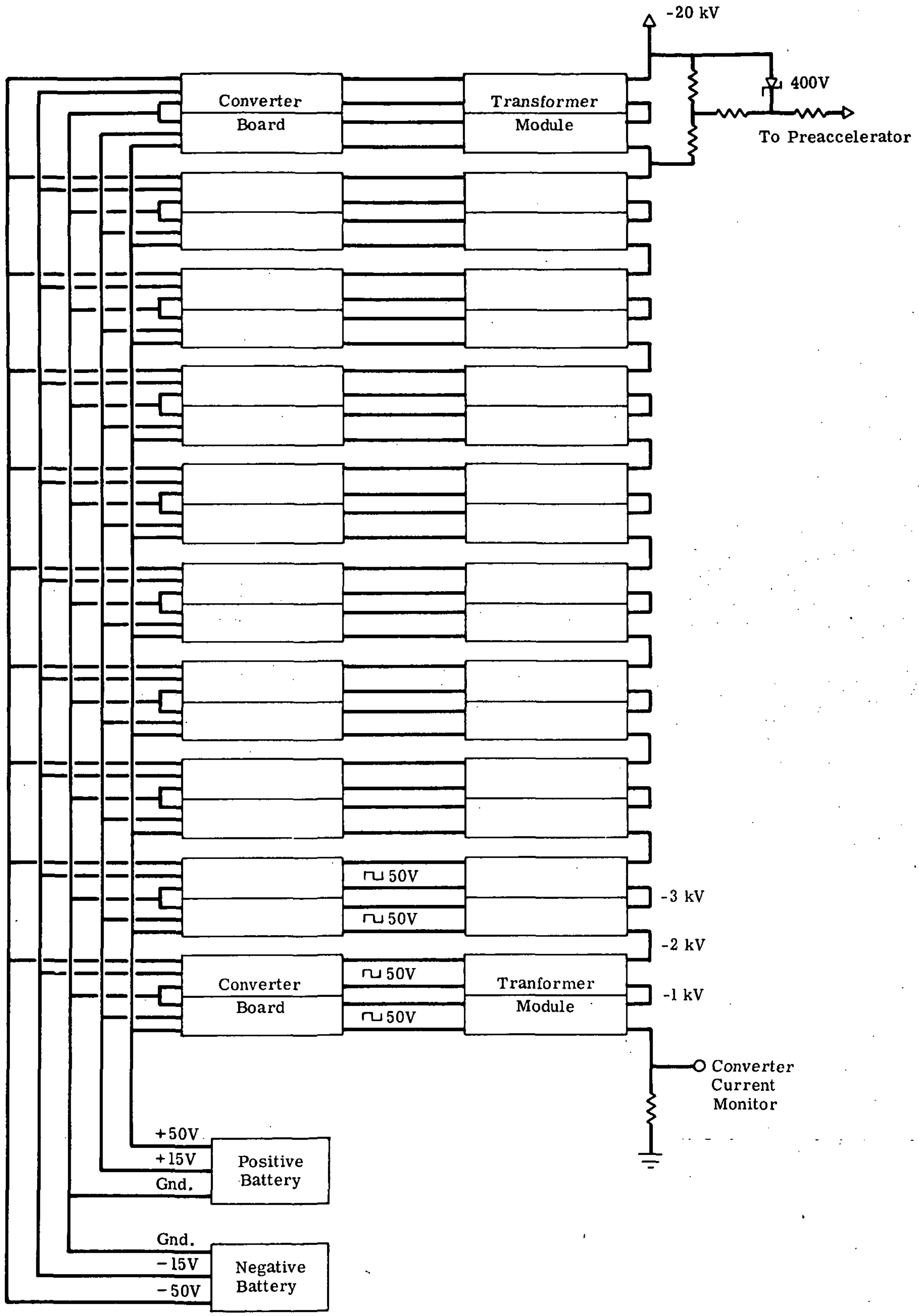
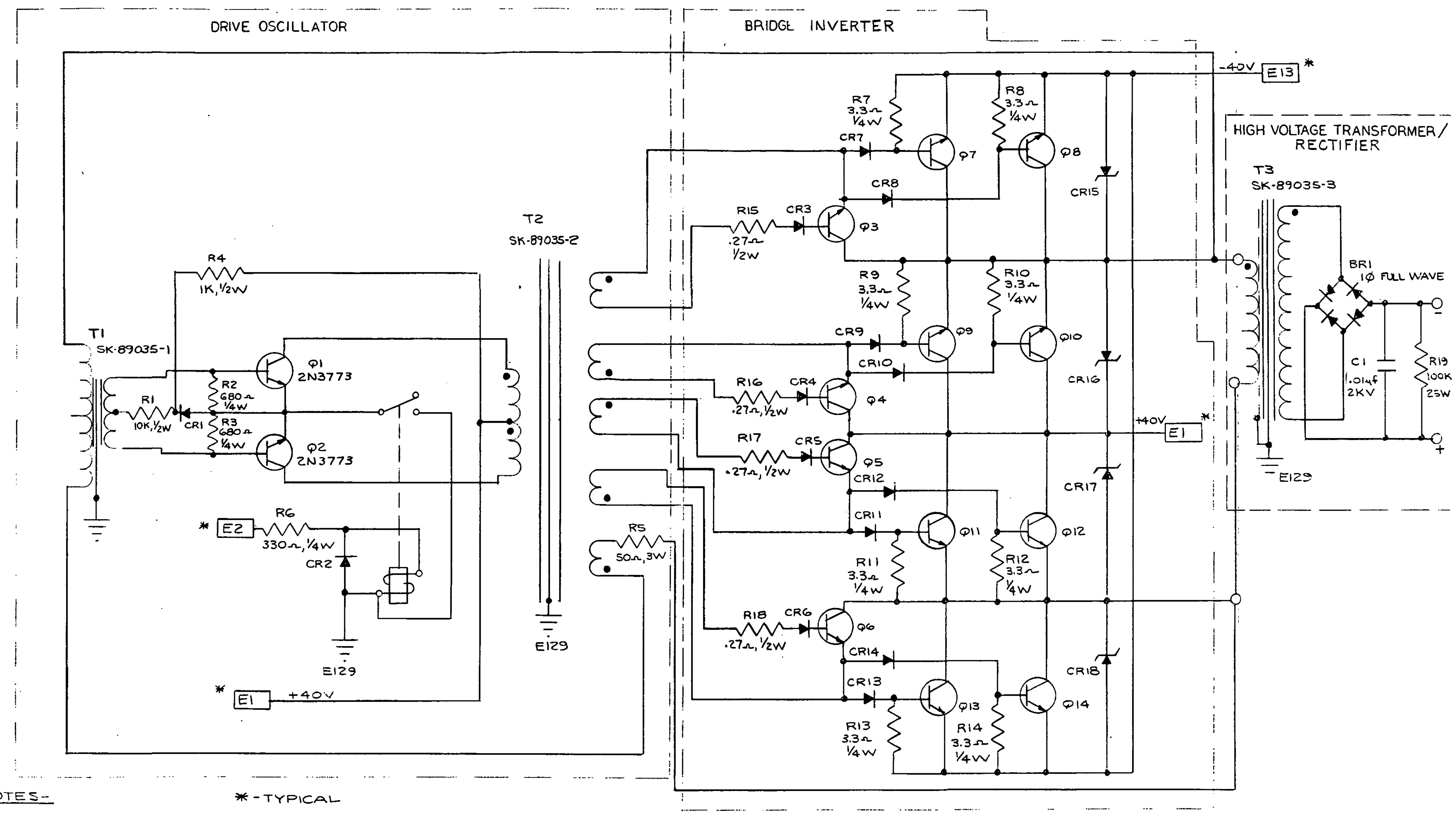


Figure 5-1. High Voltage Power Supply Block Diagram.



NOTES-

1. Q3-Q6: 2N3738
 Q7-Q14: 2N3773
 CR1-CR14: 1N4003
 CR15-CR18: UZ-217
2. DOTS ON ALL TRANSFORMERS SHOWS PHASING

* - TYPICAL

Figure 5-2. 1.0 kV - 500 mA High Voltage Converter Module Schematic.

1-6062

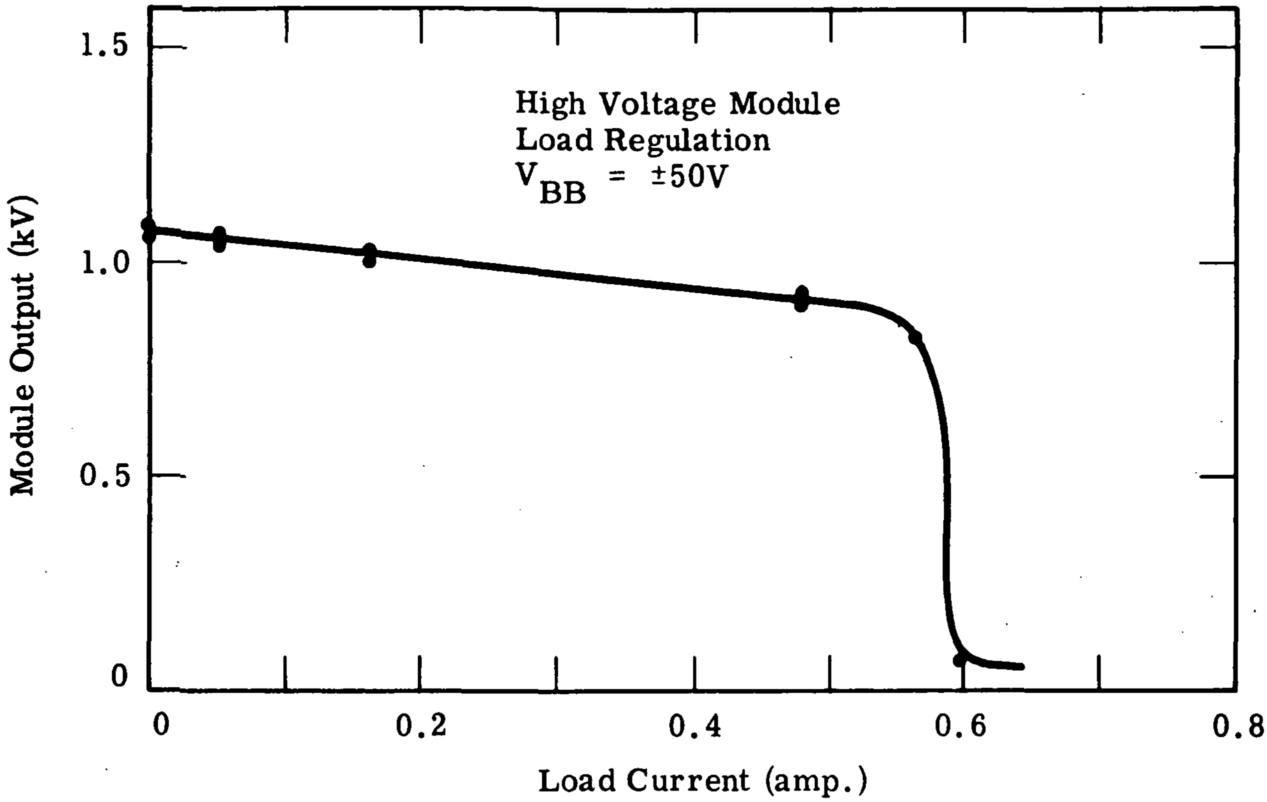


Figure 5-3. High Voltage Module Load Regulation.

SECTION 6
VACUUM INTEGRATION TESTING

The philosphy of testing the system to actual levels and conditions was continued up to the point of a simulated flight operating test, i.e., a "vacuum integration test".

During this test the payload is operated at flight levels for the specified length of the flight.

Figure 6-1 shows the test configuration. Briefly, the payload was mounted with the guns in place onto the end of our 6 x 10 foot vacuum chamber (Appendix E describes the chamber.)

The payload was connected to the ground checkout console via the umbilical cable. (Figure 6-2 shows the checkout console.)

Although the console was primarily designed to check the condition of the payload on the launcher, it had additional functions built in for the vacuum integration test at Ion Physics. These functions also made it possible to perform independent payload tests in the field.

Basically the additional functions simulated the Goddard Space Flight Center's instrumentation section which provided experiment "On" commands and telemetry channels for the data.

During the vacuum integration test at IPC we did not radiate data over a telemetry channel. We simply hard-wired the conditioned telemetry channel inputs into recorders. (Appendix A shows the test plan used and the data recorded during the test.)

It was necessary to simulate the collector screen during the vacuum integrator test. This was accomplished quite nicely by inserting in the vacuum chamber 3 Faraday cups. These cups were biased positive and the current received by each was returned to the payload.

The current from each cup was returned to the skin through the actual current monitoring circuits to be used during the flight. One monitor for each cup and one monitor for the total current of all cups.

In order to facilitate the vacuum integration test a dummy load was constructed. The dummy load permitted checkout of the power conversion portion of the system and most telemetry conditioning circuits at flight levels before a set of flight qualified guns or battery were committed to the tests. (The payload could be completely checked out before opening the flight type guns in the vacuum chamber at much lower power levels.) The intent of the dummy load tests was the production of equivalent heat loads on the complete flight programs.

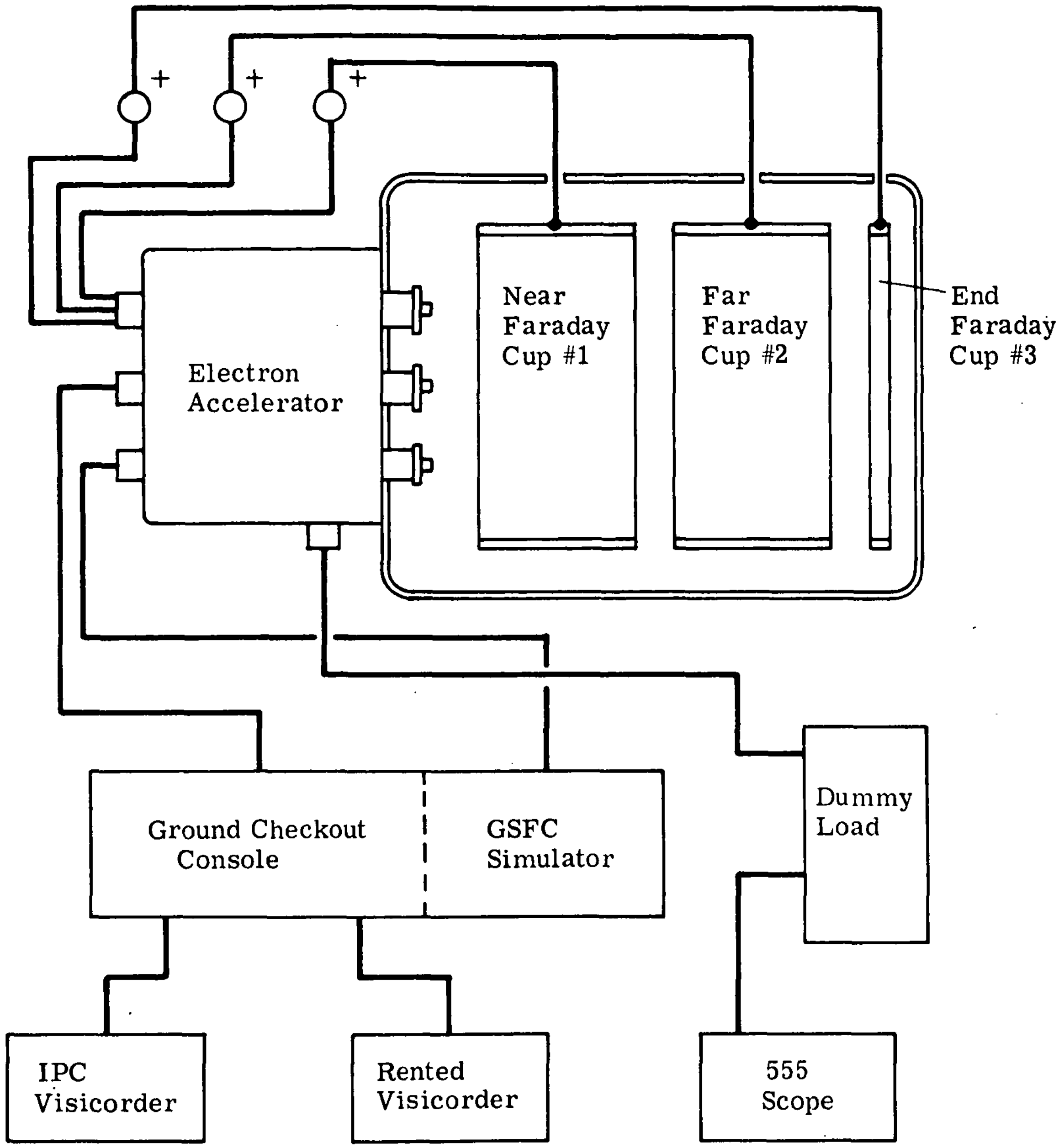


Figure 6-1. Vacuum Integration Testing.

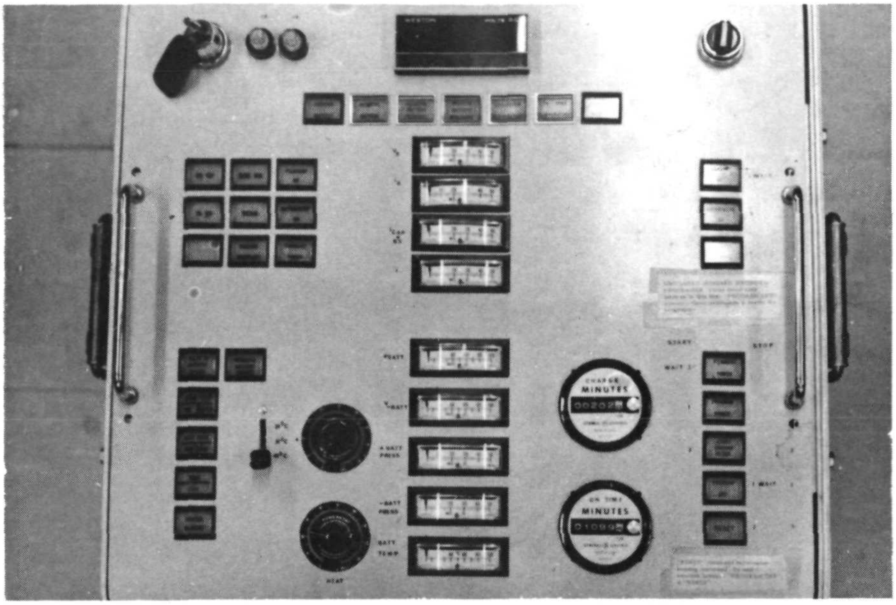


Figure 6-2. Check-out Console.

RESUMES

DR. HELMUT MILDE

Manager
Power Systems Division

Education

Diplom Ing., School of Electrical Engineering, Technical University of Graz, 1960.

M. S., Electrical Engineering, Massachusetts Institute of Technology, 1962.

Ph.D., Technical University of Graz, 1966.

Professional Experience

1966 - present — Ion Physics Corporation. Has managerial responsibility for the design and fabrication of a 20 keV rocket-borne electron beam injector. Engaged in the conceptual design and experimental work of high voltage nanosecond pulse systems. Was Project Manager on the design and construction of the first completely triggered megavolt water insulated pulse generator (Neptune). Was Project Physicist on the design of a four megavolt EMP generator (ARES). Work includes design and development of stacked line pulse circuits, pulse transformers, fast Marx generators, as well as research in dielectric properties (breakdown strength, arc recovery, delay and jitter) of various switching media. Also studied laser triggering of megavolt switches.

1963-66 — Brown, Boveri and Company. Engaged with plasma diagnostics in connection with MHD-generators and later worked on the economic aspects of MHD-generators. Also studied the field of laser applications. This work included interferometric length measurement, measurement of the gas velocity by doppler shift, determination of droplet size distribution in steam turbines, as well as studies on current measurement on high voltage transmission lines.

1960-63 — Massachusetts Institute of Technology. High Voltage Research Laboratory. As a Research Assistant, work included research on barium absorption pumps and on the production of intense ion and neutral beams. Later as a Staff Member, continued work on ion beams.

DR. HELMUT MILDE (Continued)

Publications and Patents

"Barium Absorption Pumps", with R. W. Cloud and S. F. Philp, Transactions of the Eighth Vacuum Symposium, 352 (1961).

"Production and Control of a High Energy Neutral Particle Beam", M.S. Thesis, Massachusetts Institute of Technology (1962).

"Measurement of Current Density Distribution and Emittance of a Positively Charged Ion Beam", Ph.D. Thesis, Technical Institute of Gras (1966).

"Electrodeless Conductivity Measurements within the Reaction Zone of a Combustion Chamber", with H. Gallant, MHD Power Generation Conference (1966).

"Insulation Breakdown and Switching in High Pressure Gases", with M. J. Mulcahy and W. R. Bell, Eighth Electrical Insulation Conference, Los Angeles, California (December 1968).

"Switching of Fast High Voltage Pulse Generators", with J. J. Moriarty, High Voltage Technology Seminar, Boston, Massachusetts (September 1969).

"Precise Laser Initiated Closure of Multimegavolt Spark Gaps", with J. J. Moriarty, J. R. Bettis, and A. H. Guenther, The Review of Scientific Instruments 42, No. 12, 1767 (1971).

"Transient Effects in UHV Tandem Accelerators" with P. H. Rose, Particle Accelerator Conference, Chicago (1971).

APPENDIX A

VACUUM INTEGRATION TEST DATA

APPENDIX A

VACUUM INTEGRATION TEST DATA

Test Objective:

To completely test all critical functions of the 20 keV electron accelerator, designed and built under NASA contract number NASA 9-10399, under as closely simulated space conditions as possible.

Test Method:

The 20 kV accelerator will be mounted on the IPC vacuum chamber.

The unit will be given simulated control commands which will cycle the payload through a complete flight program of output pulses.

A copy of the flight program is included in Appendix I.

The test will be conducted according to the following check list.

VACUUM INTEGRATION TEST CHECK LIST

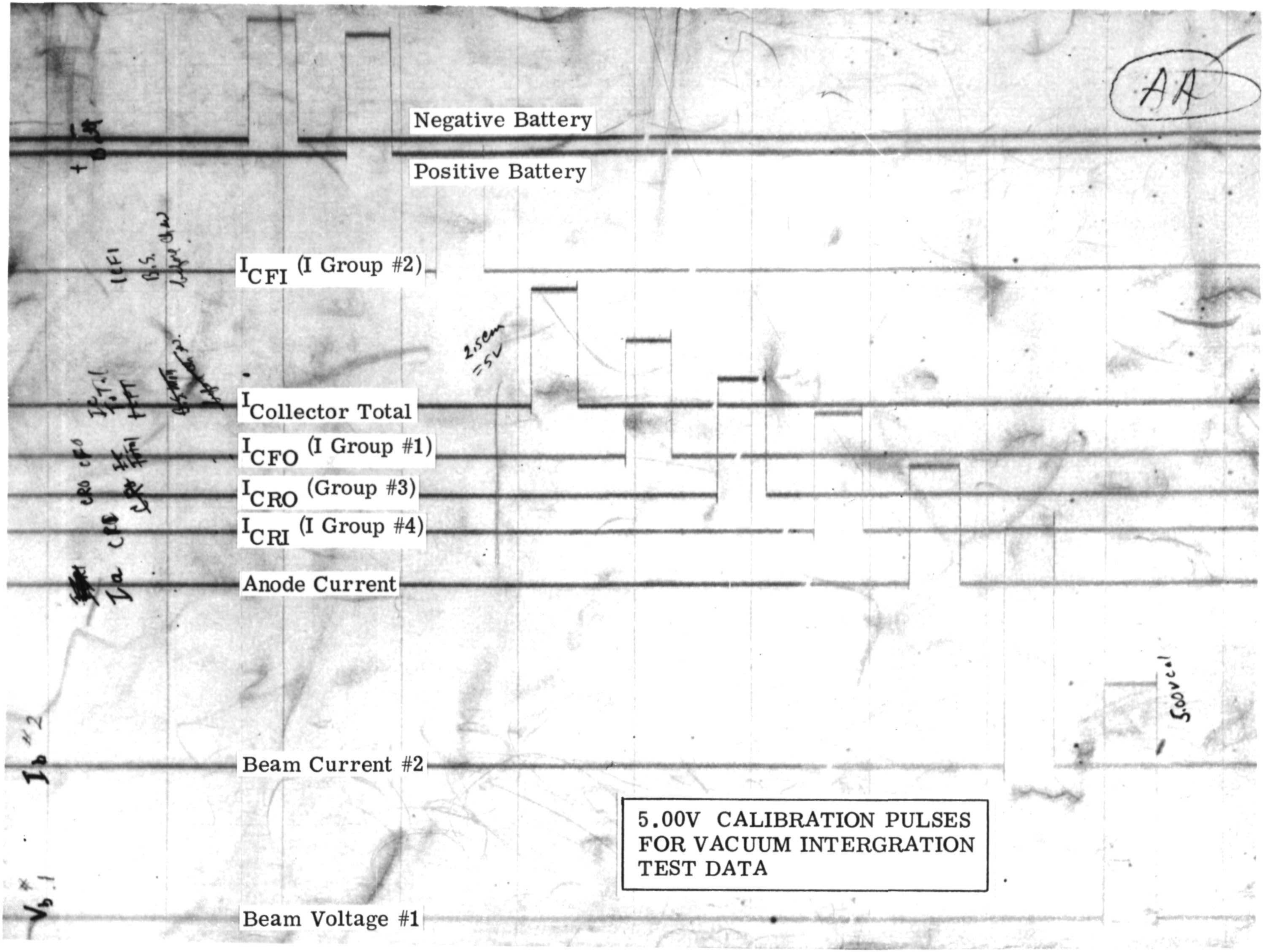
Item	Personnel	Time
Fill ±Batt	C. Salisbury	t-72 hrs.
Set up Camera's	P. Thomas	t-4 hrs.
±Batt Heaters on	C. Salisbury	t-60 min.
Faraday's Connected-Ground Check Program	R. Harrison	t-30 min.
Viscorder Cal.	C. Salisbury	t-15 min.
Viscorder Paper Check	C. Salisbury	t-15 min.
Scope Film Check	P. Thomas	t-15 min.
Gate Valve Open - Vacuum Chamber Press	A. Lambert	t-14 min.
+B.S. Armed	R. Harrison	t-10 min.
-B.S. Armed	R. Harrison	t-10 min.
T/M "on"	R. Harrison	t-10 min.
Positive Battery Voltage	C. Salisbury	t-9 min.
Negative Battery Voltage	C. Salisbury	t-9 min.
Convertor Temperature		t-8 min.
T/M Temperature		t-8 min.
#1 Battery Pressure		t-8 min.
#2 Battery Pressure		t-8 min.
#1 Battery Temperature		t-8 min.
#2 Battery Temperature		t-5 min.
Dummy Load (Out)		t-5 min.
Tuner "on" - Fil "on"		t-40 sec.
Viscorder "on" slow		t-15 sec.
Viscorder "on" fast		t-5 sec.
Exp. "on"		t = 0
Scope Pictures		from t = 0 to t + 5 min.
Photos		t = 0 to t + 5 min.

VACUUM INTEGRATION TEST CHECK LIST (Continued)

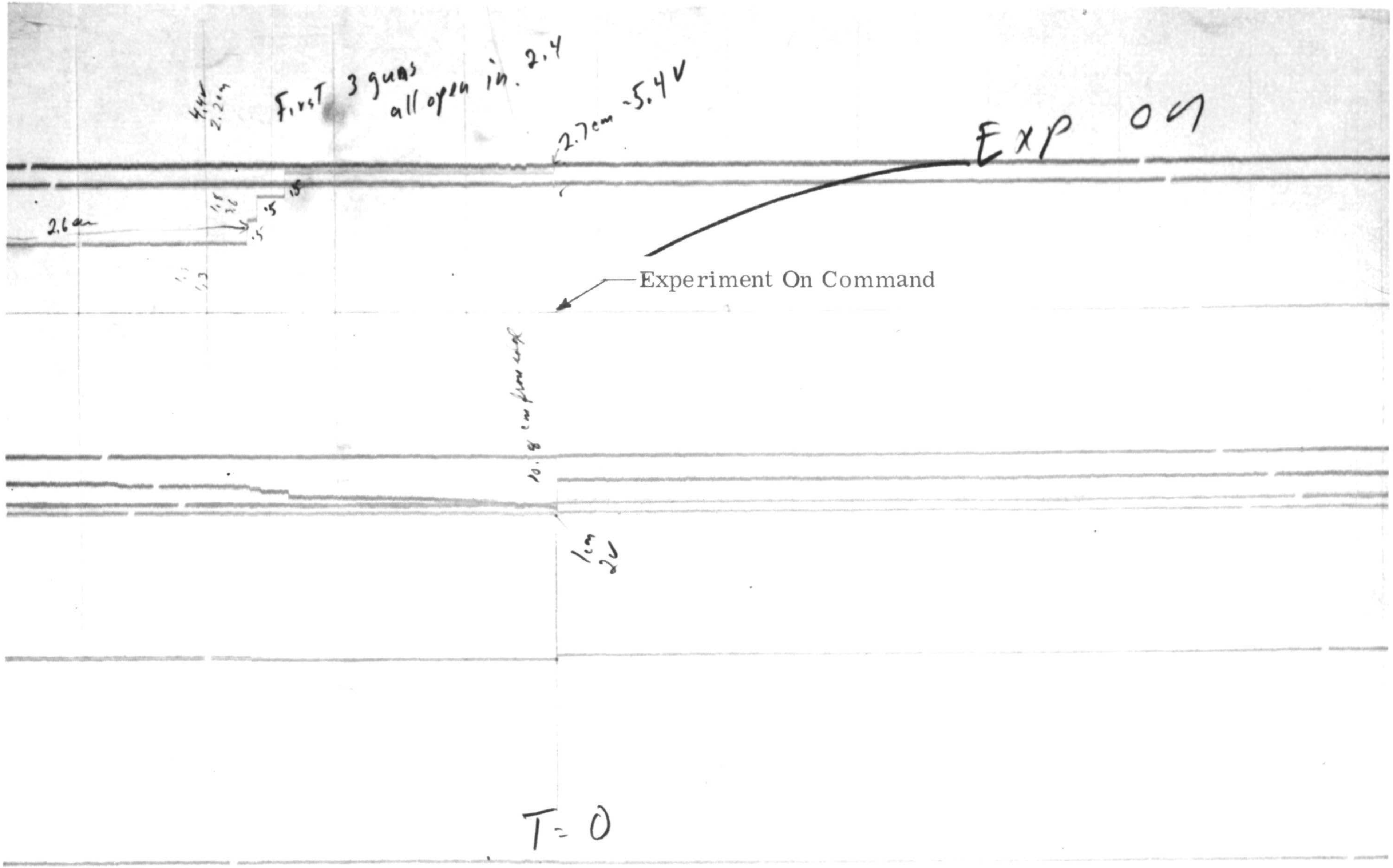
Item	Personnel	Time
Vacuum Chamber Pressure Readings		t + 4 sec. to t + 15 sec.
Vacuum Chamber Pressure		t + 1 min.
Vacuum Chamber Pressure		t + 2 min.
Vacuum Chamber Pressure		t + 3 min.
Vacuum Chamber Pressure		t + 4 min.
Vacuum Chamber Pressure		t + 5 min.

MONITOR LIST FOR VACUUM TEST OF 12.0.8 (20 kV Accelerator)

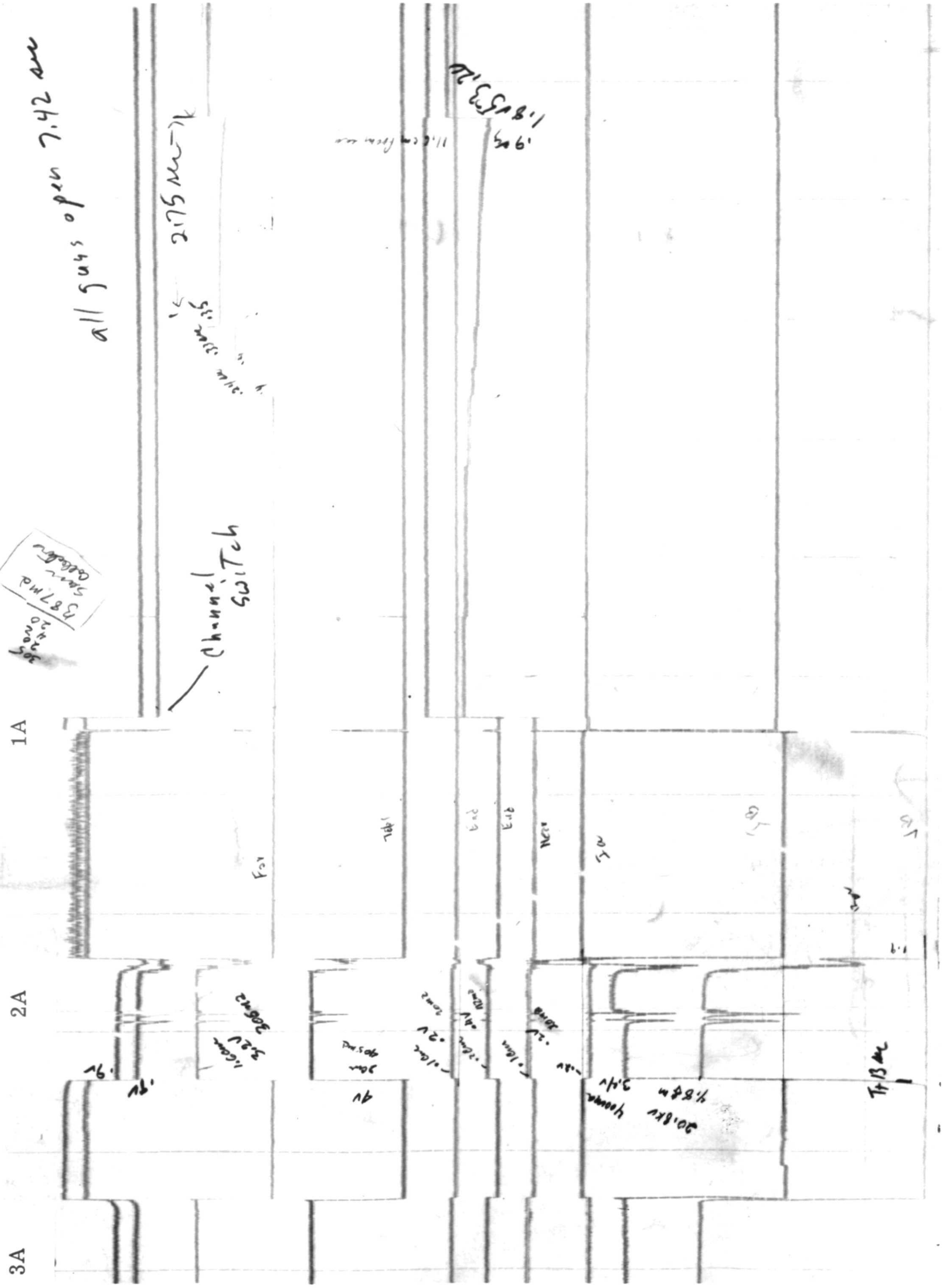
Function	Type of Instrument	Remarks	Sensitivity	Sweep
Beam Voltage #1	Viscorder (IPC)	Critical		
Beam Voltage #2	Viscorder + Scope (IPC)	Critical		
Anode Current	Viscorder (IPC)	Critical		
Collector Current Total	Viscorder (IPC)	Critical		
Faraday #1 (Near)	Viscorder Ret	Critical		
Faraday #2 (Far)	Scope Viscorder Ret	Critical		
Faraday #3 (End)	Scope Viscorder Ret	Critical		
Breakseal Monitor	Scope Viscorder (IPC)	Critical		
Negative Battery Voltage	Scope Viscorder (IPC)	Critical		
Positive Battery Voltage	Scope Viscorder (IPC)	Critical		
Beam Voltage #2	Viscorder	Optional		
Beam Voltage Directly	Scope	Optional		
Beam Current #1	Viscorder + Scope	Optional		
Collector (CRI)	Viscorder (IPC)	Optional		
Collector (CRO)	Viscorder (IPC)			
Collector (CFI)	Viscorder (IPC)			
Collector (CFO)	Viscorder (IPC)			
Package Temperature	ret Viscorder			
Fil Current RO	ret Viscorder			
Exp "on" Monitor	Console			
10 kV Comm. Monitor	Console			
20 kV Comm. Monitor	Console			
500 mA Comm. Monitor	Console			
Fil "on" Comm. Monitor	Console			
T/M Temperature	Voltmeter			
Battery #2 Pressure	ret Voltmeter			
Battery #1 Pressure	ret Voltmeter			
Package Pressure	Voltmeter			
Battery #1 Temperature	Voltmeter			
Battery #2 Temperature	Voltmeter			



5.00V CALIBRATION PULSES
FOR VACUUM INTERGRATION
TEST DATA



VACUUM INTEGRATION TEST DATA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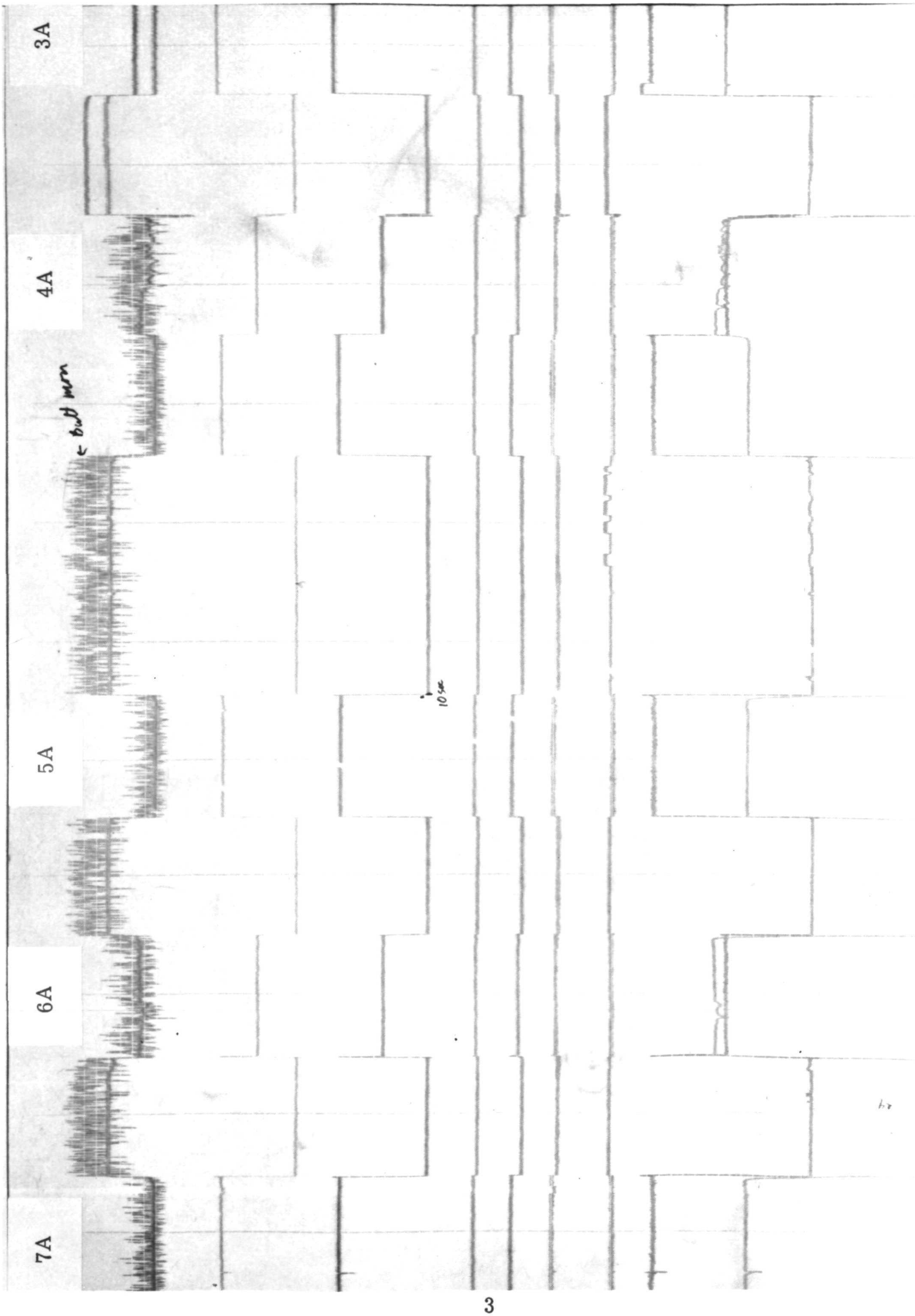
2A
3A
all guns open 7.42 sec
2175 Mc
Channel switch
387 ma
30.8 kv
T+13 sec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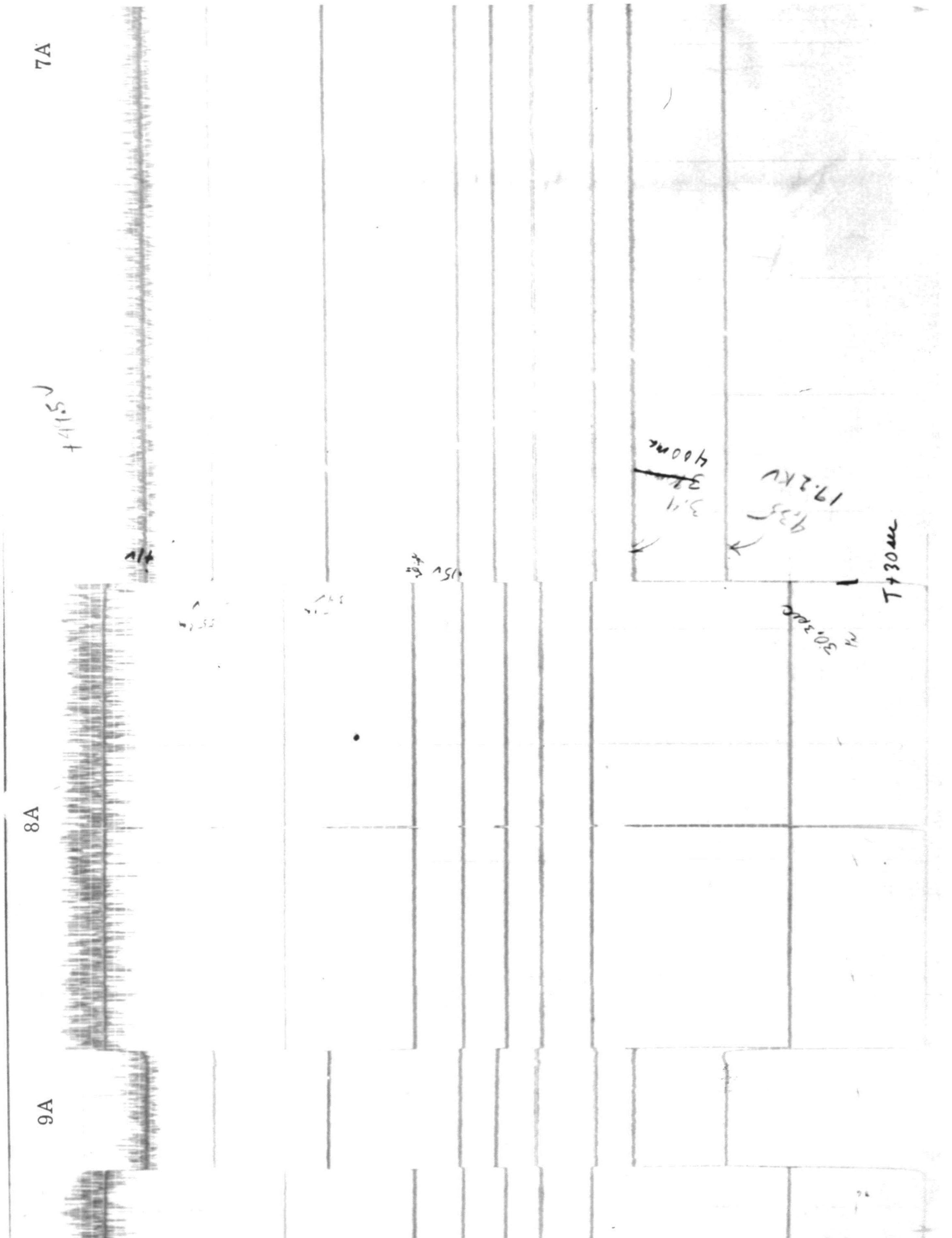
4A
5A
6A
7A
10 sec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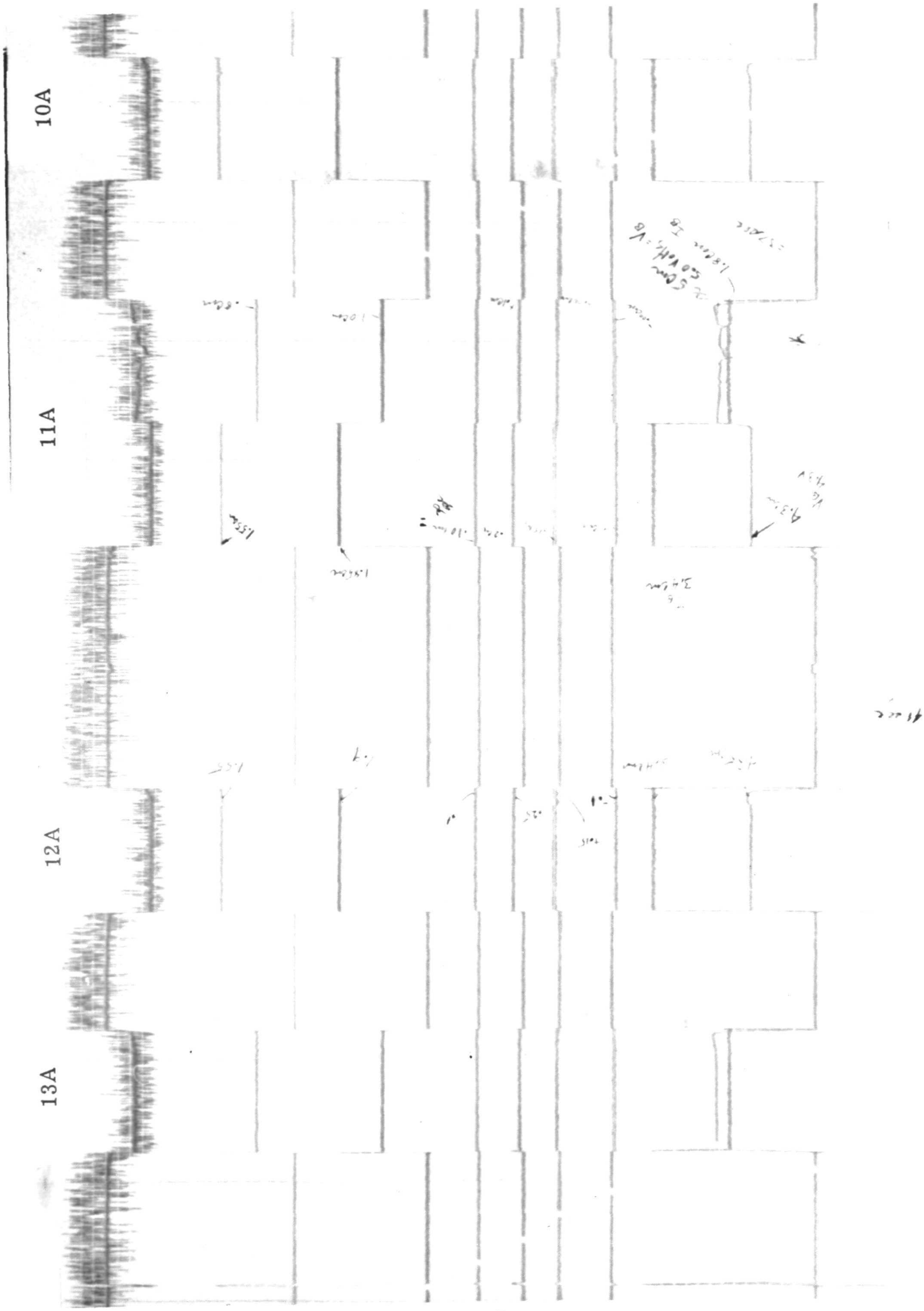
9A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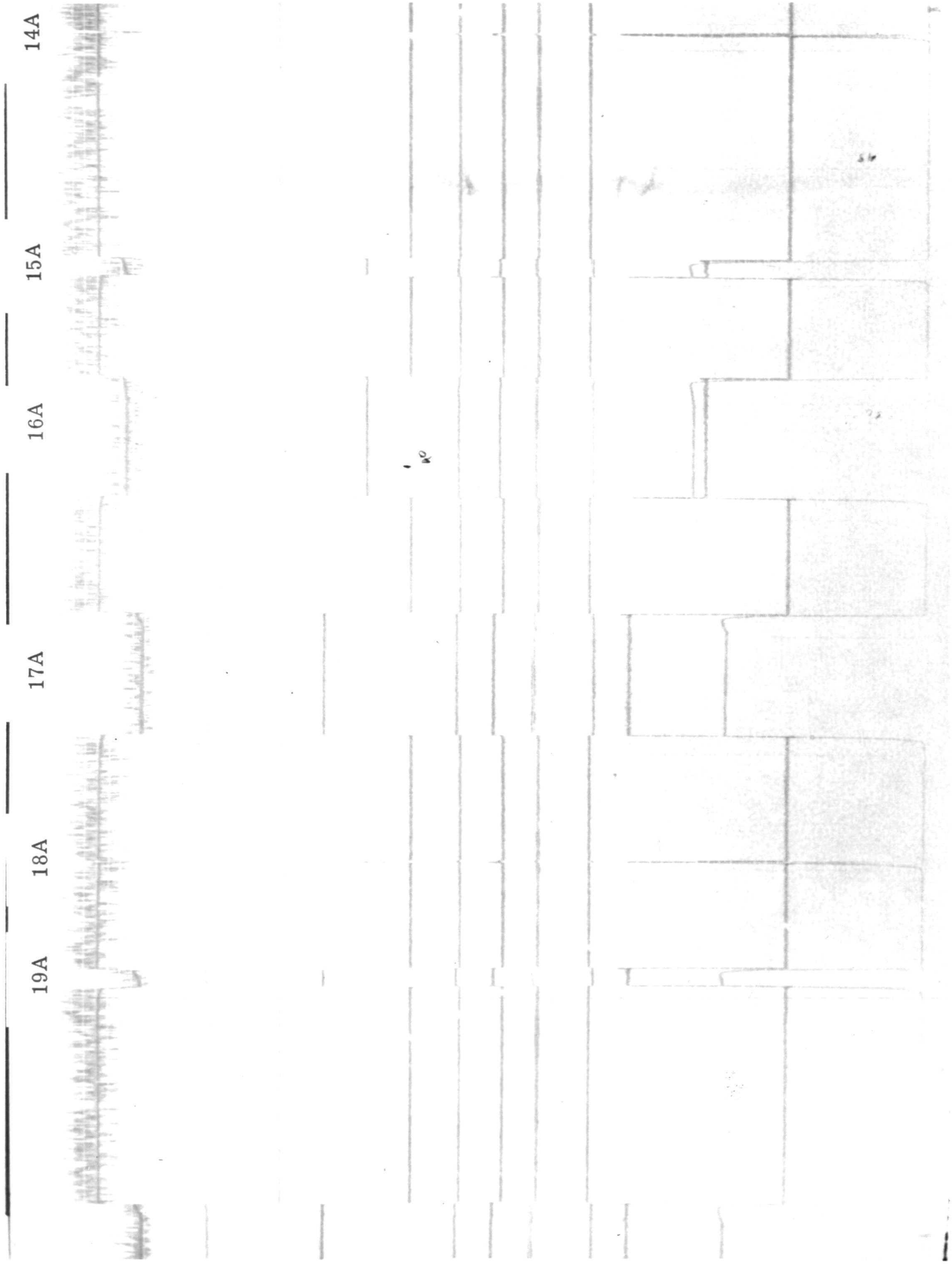
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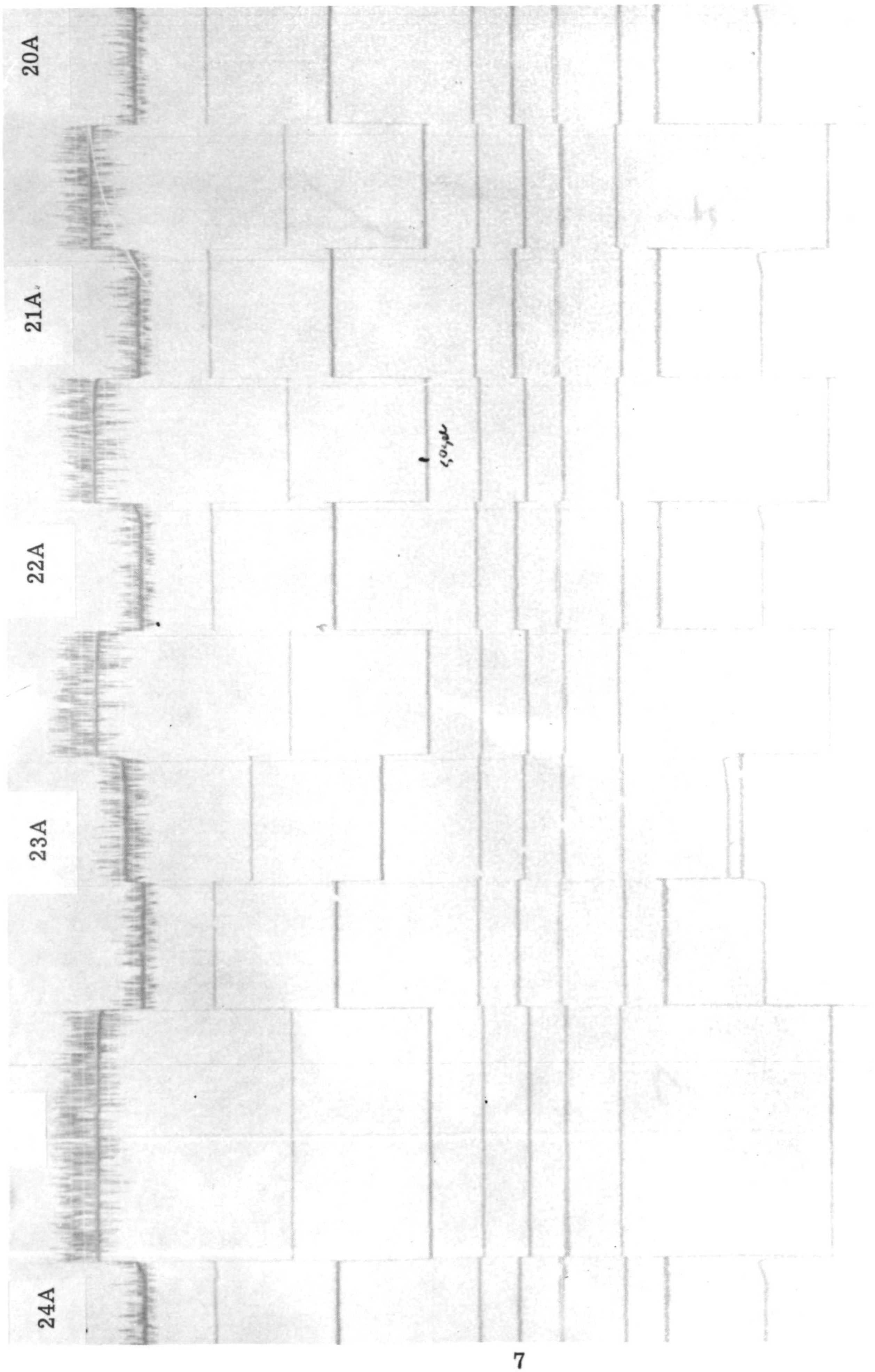

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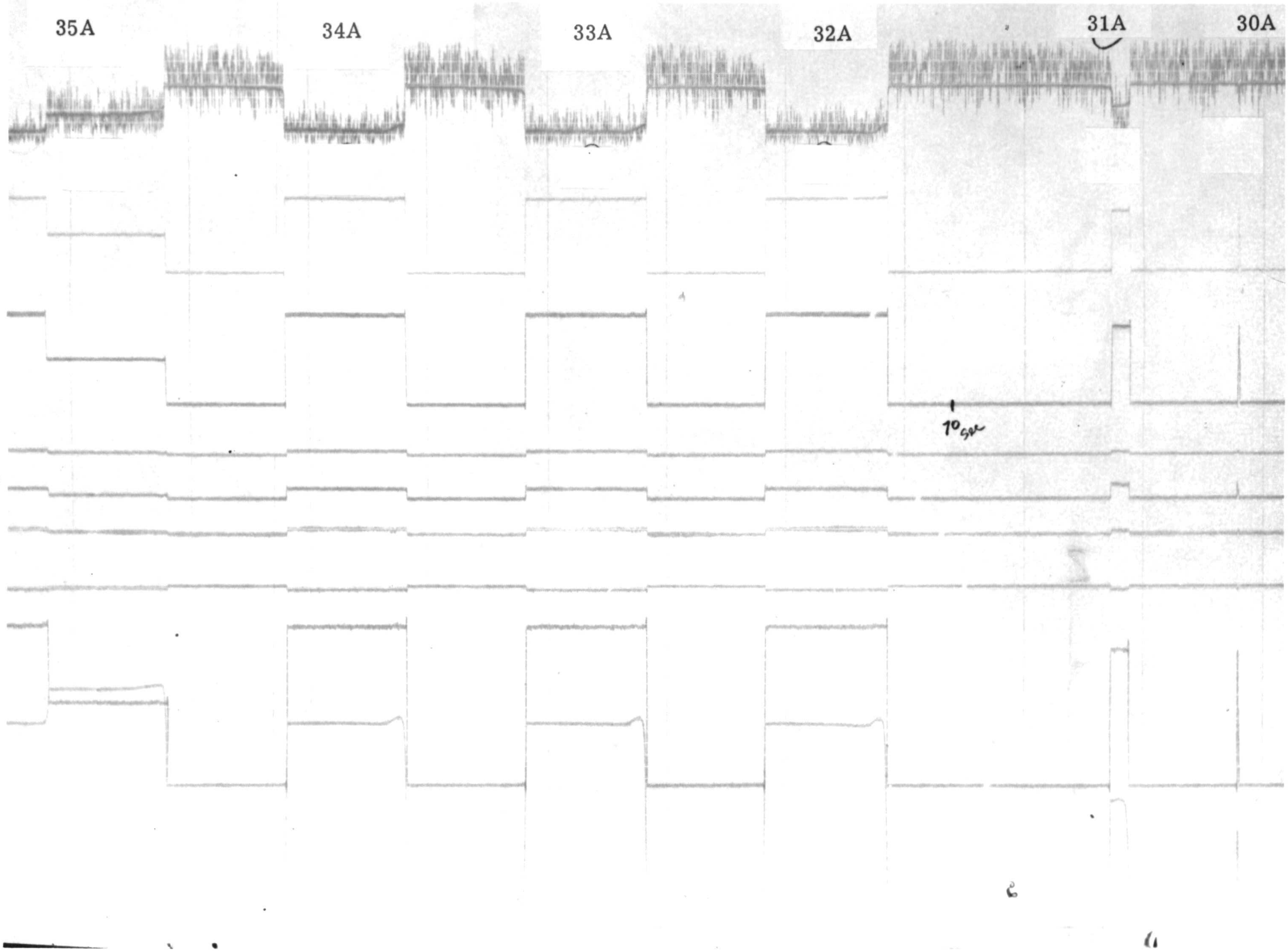
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30A
10 sec


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38A
39A
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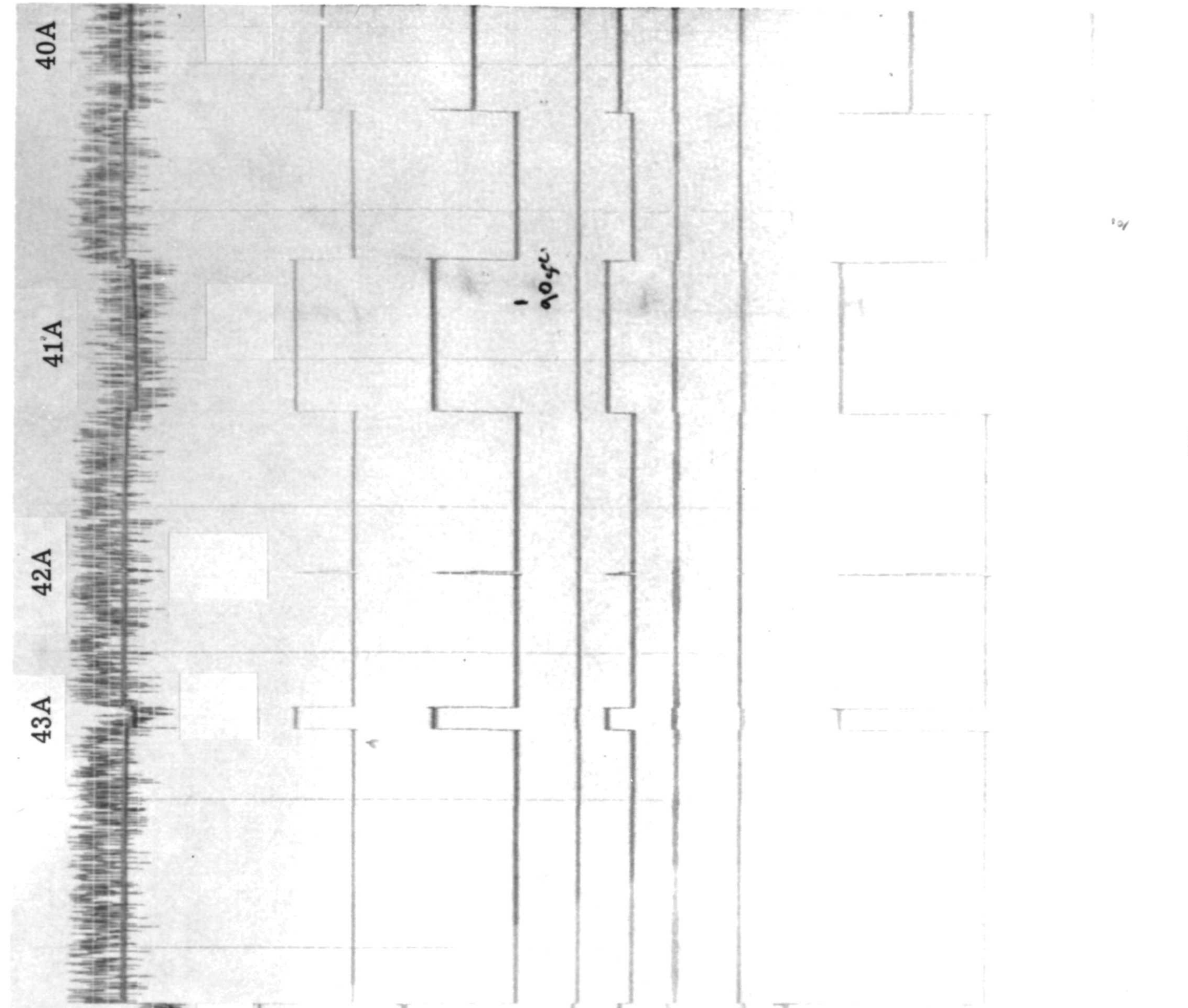
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41A
42A
43A
44A
1B


2B
3B
4B
5B


6B
7B
8B
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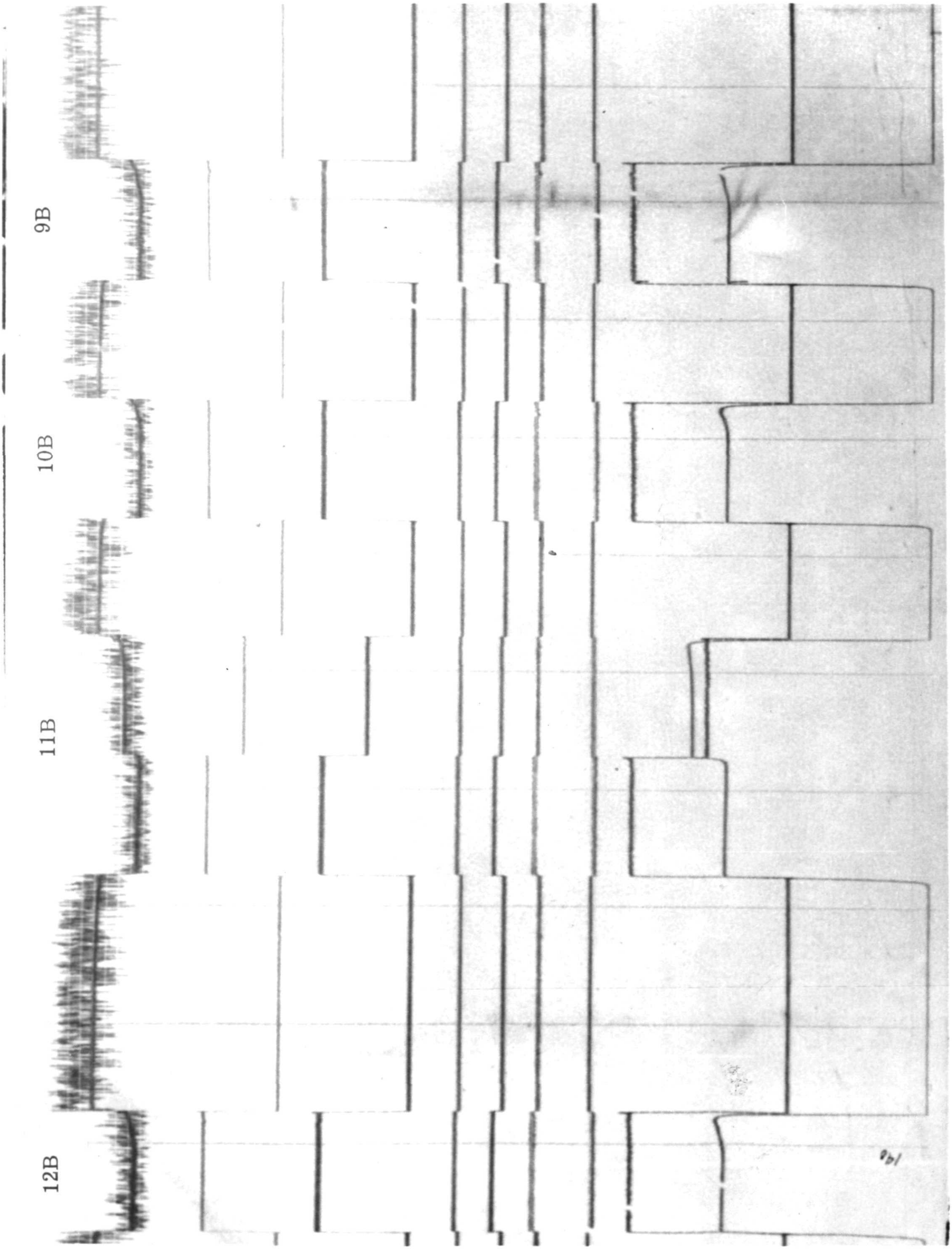
120
121
130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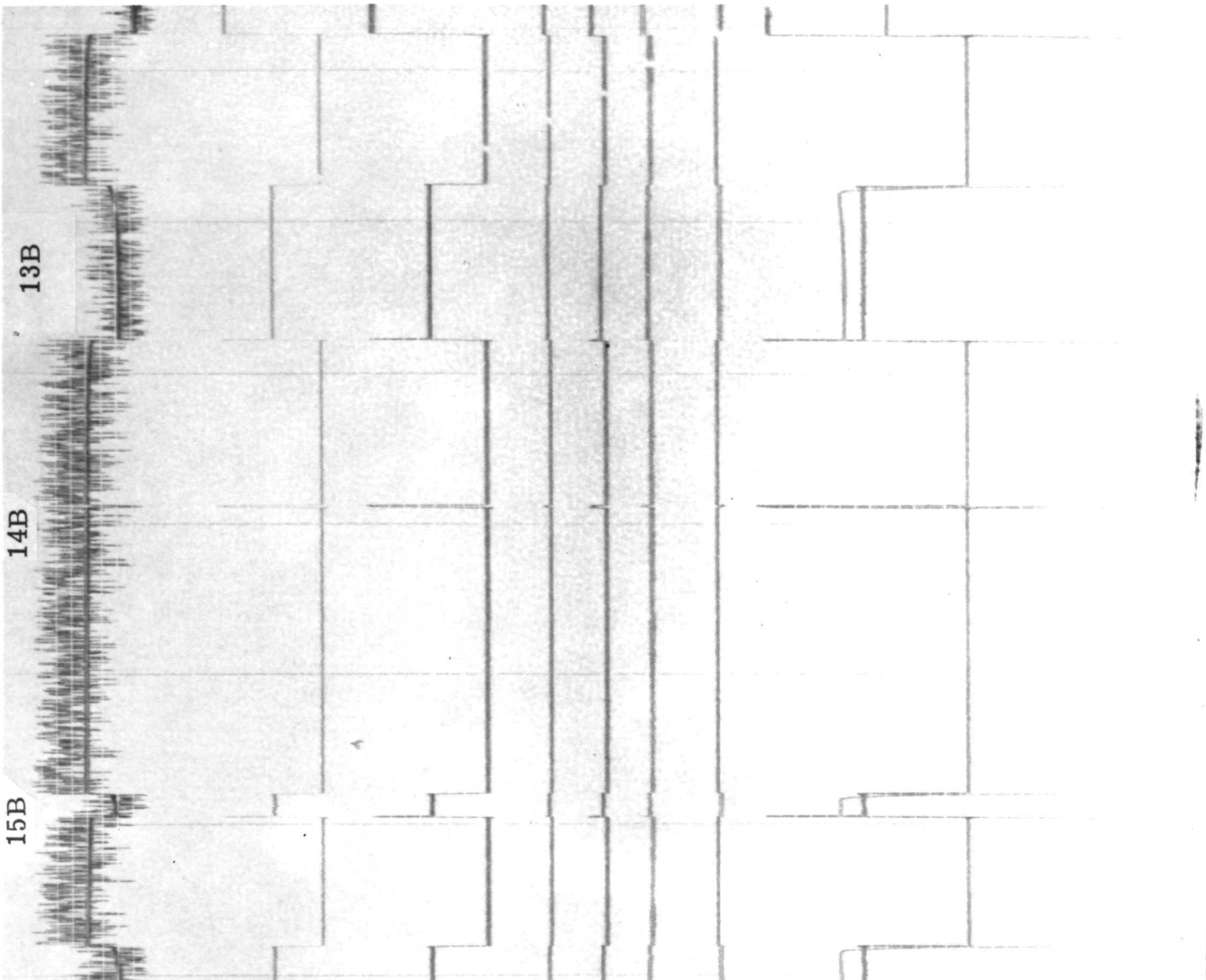
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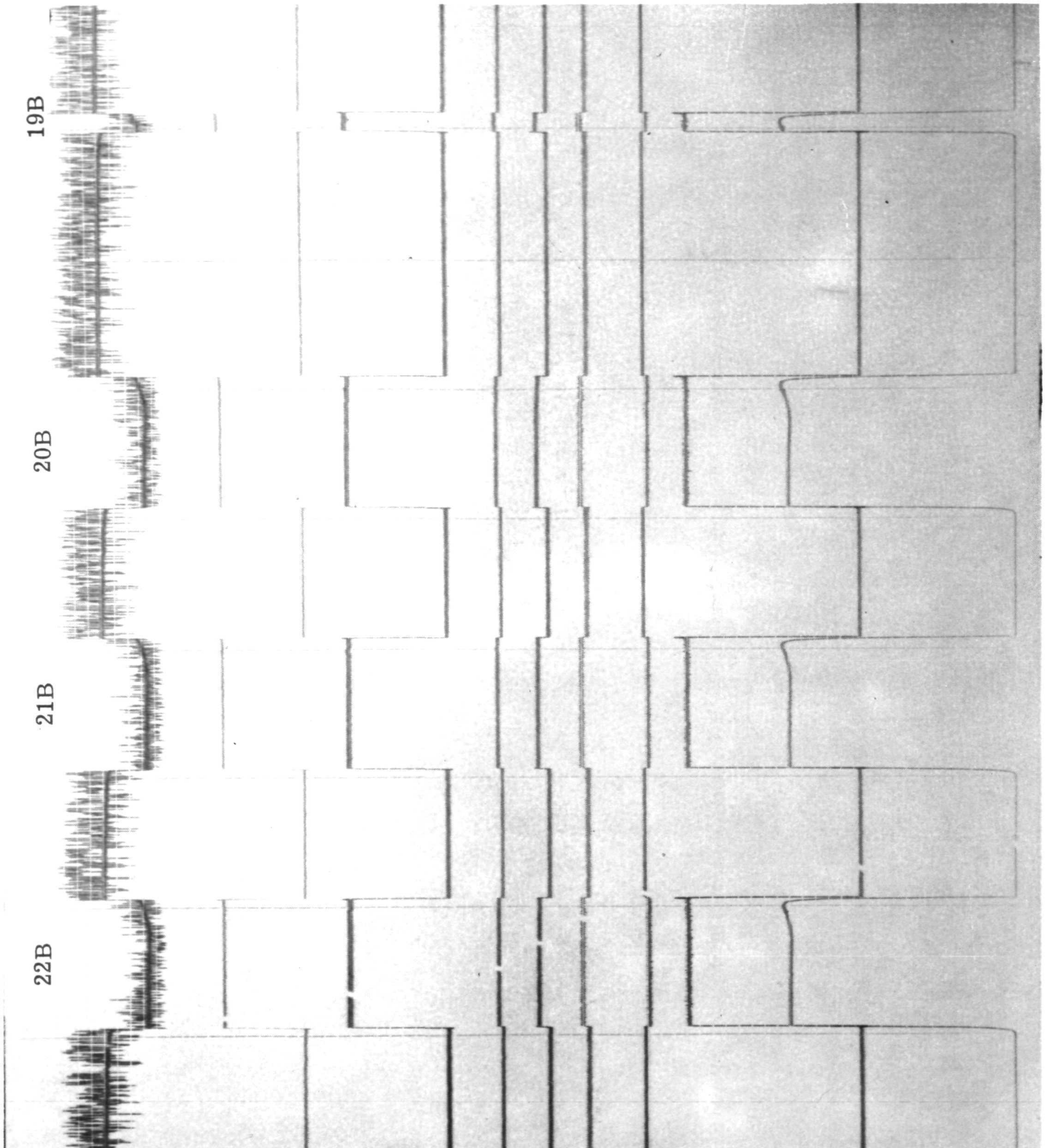

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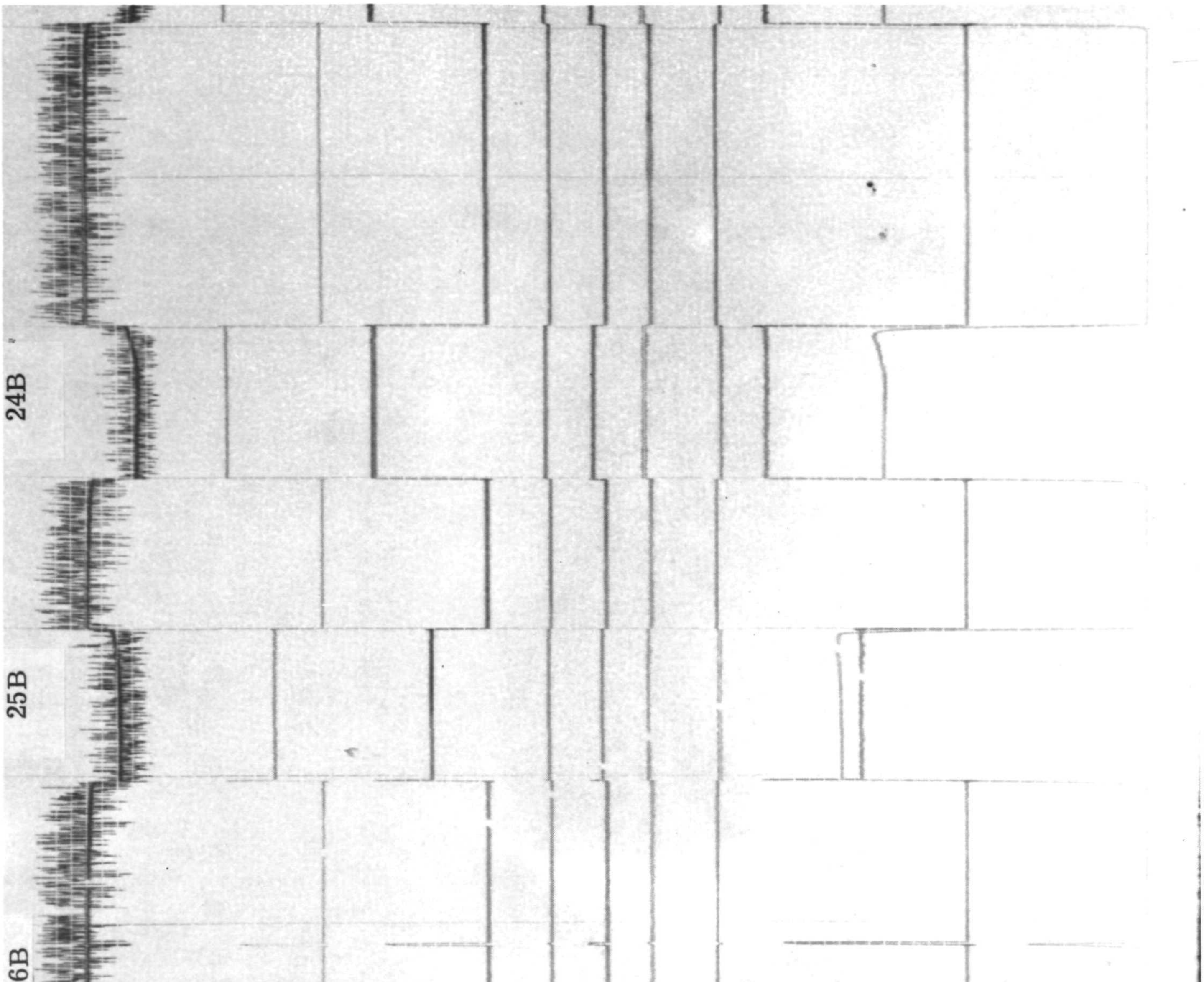
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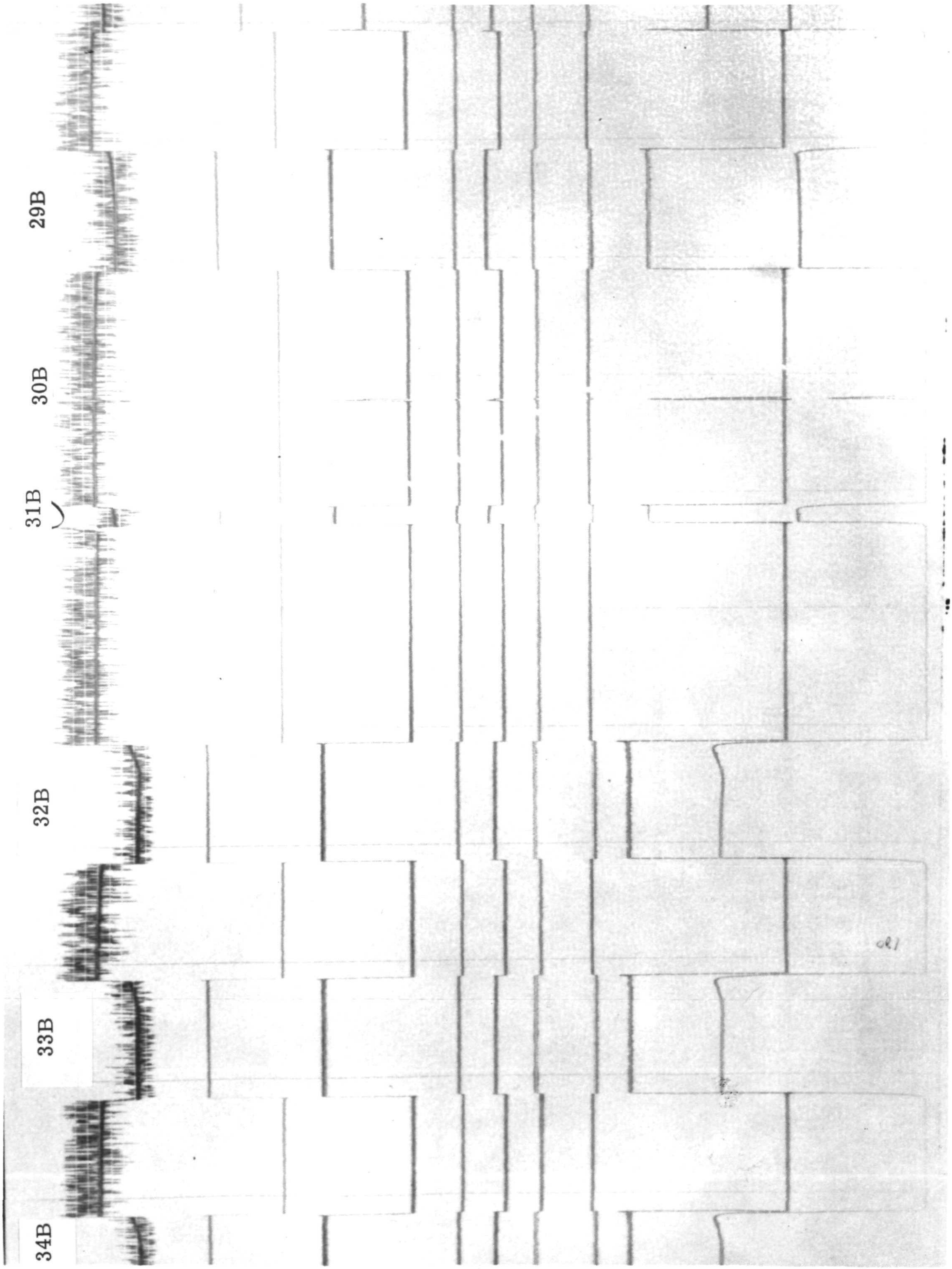
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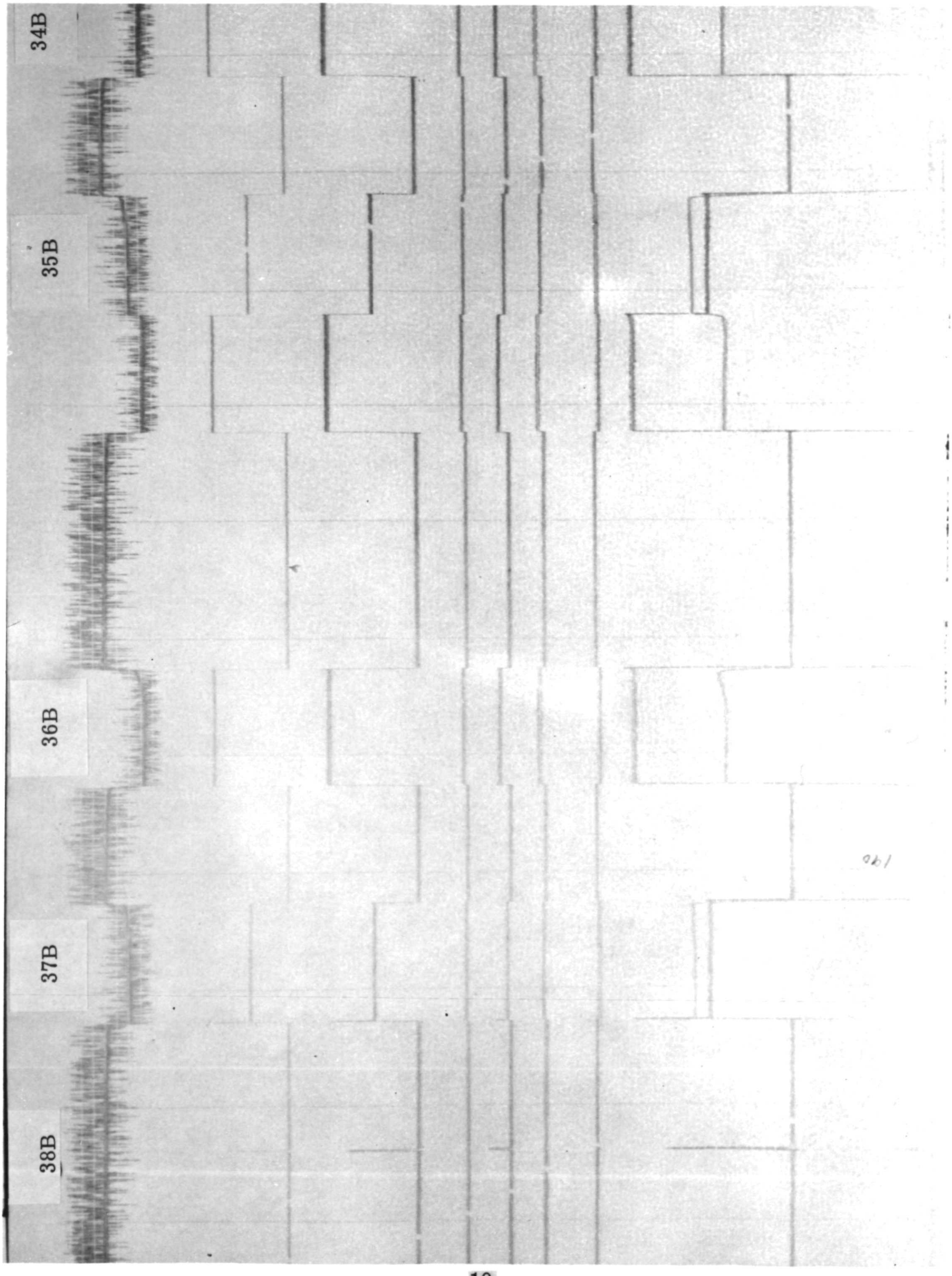
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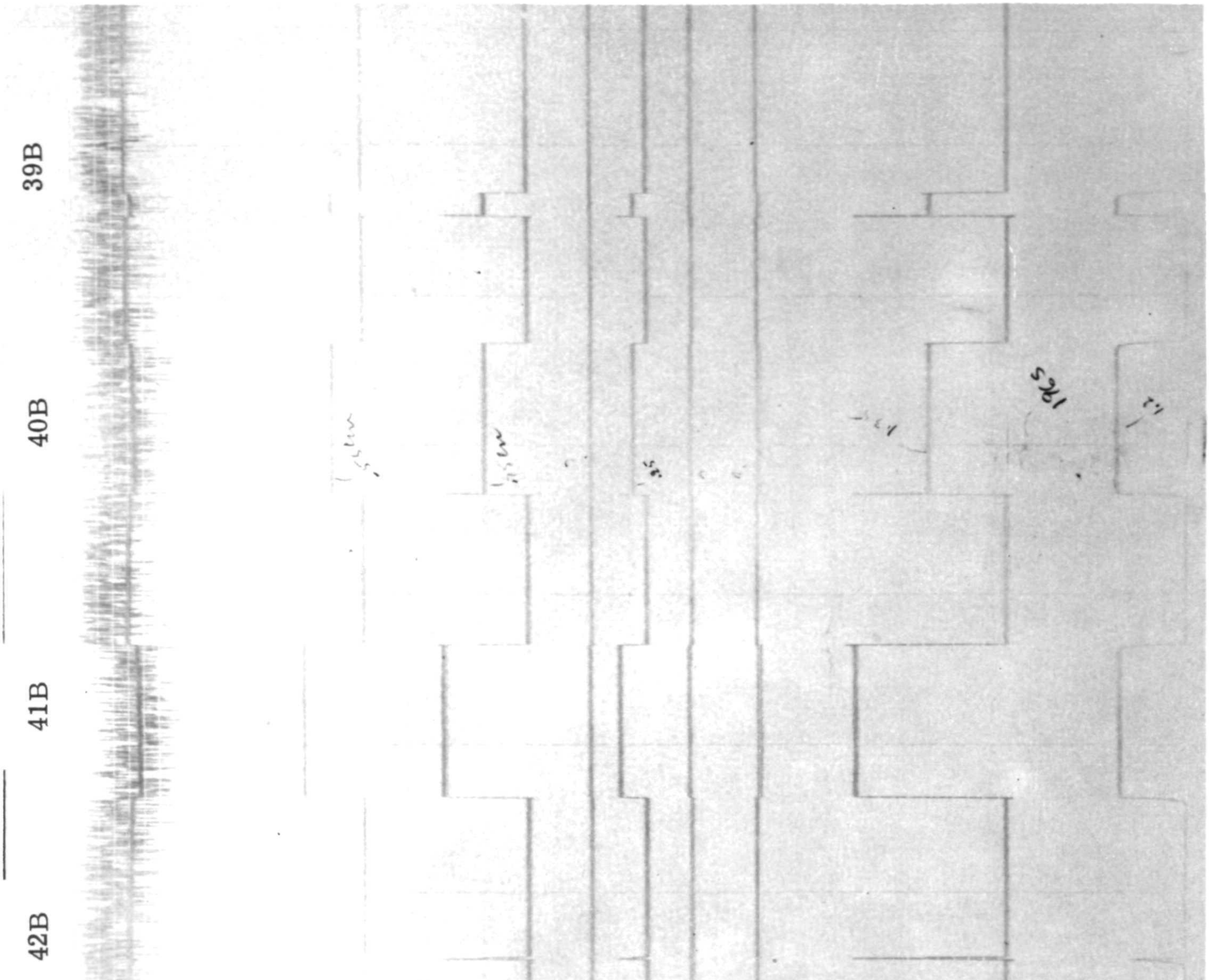
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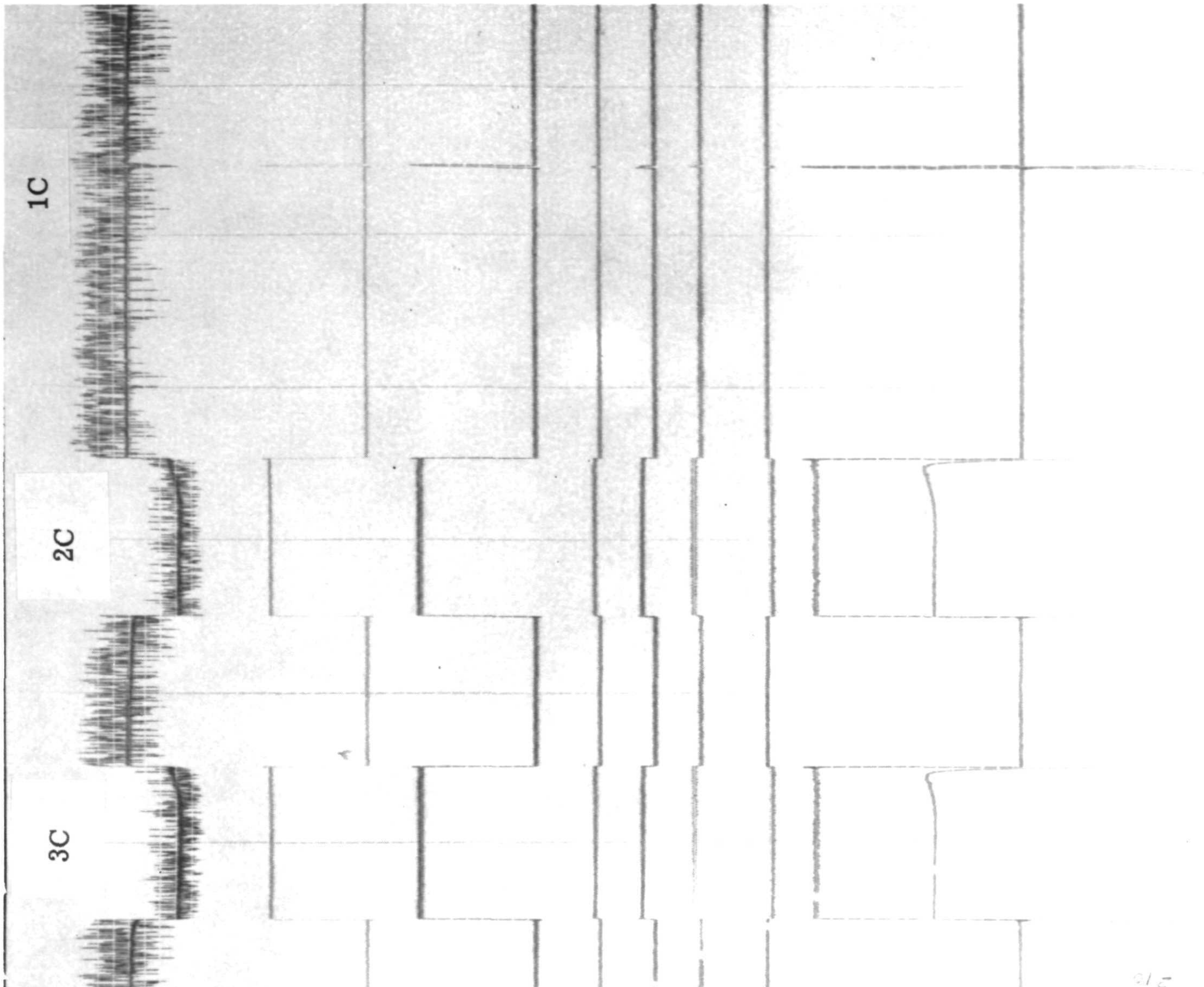
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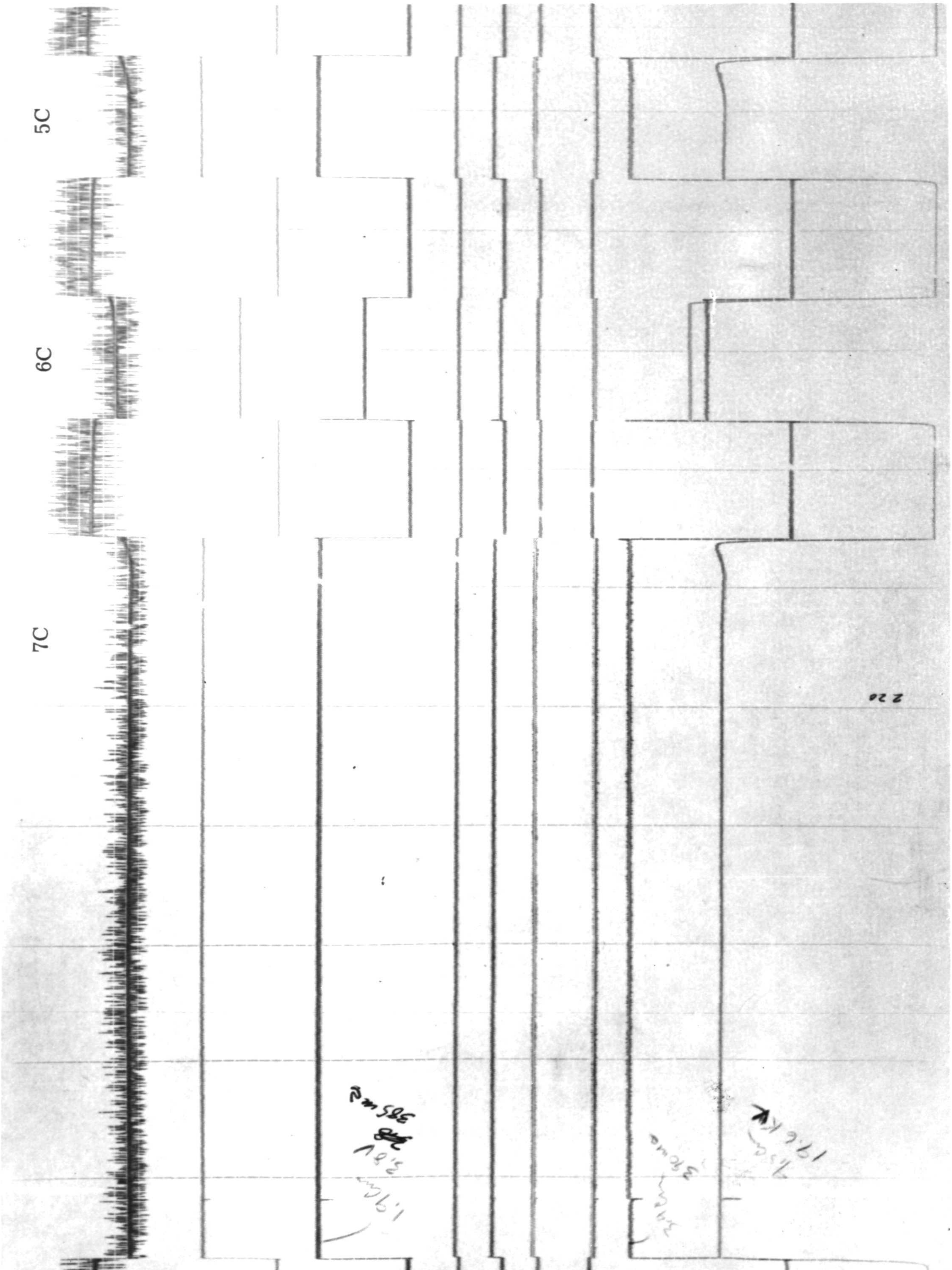
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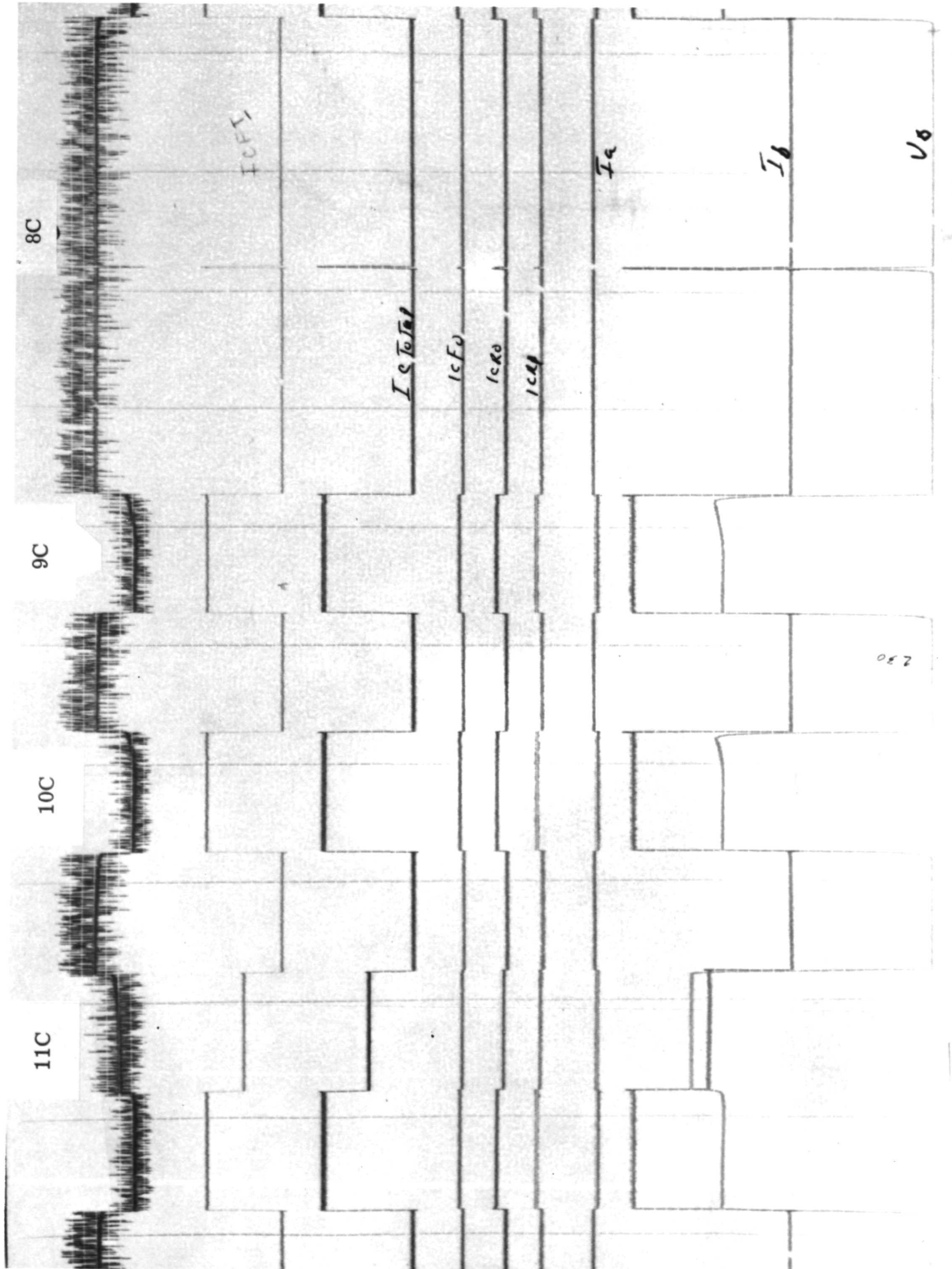
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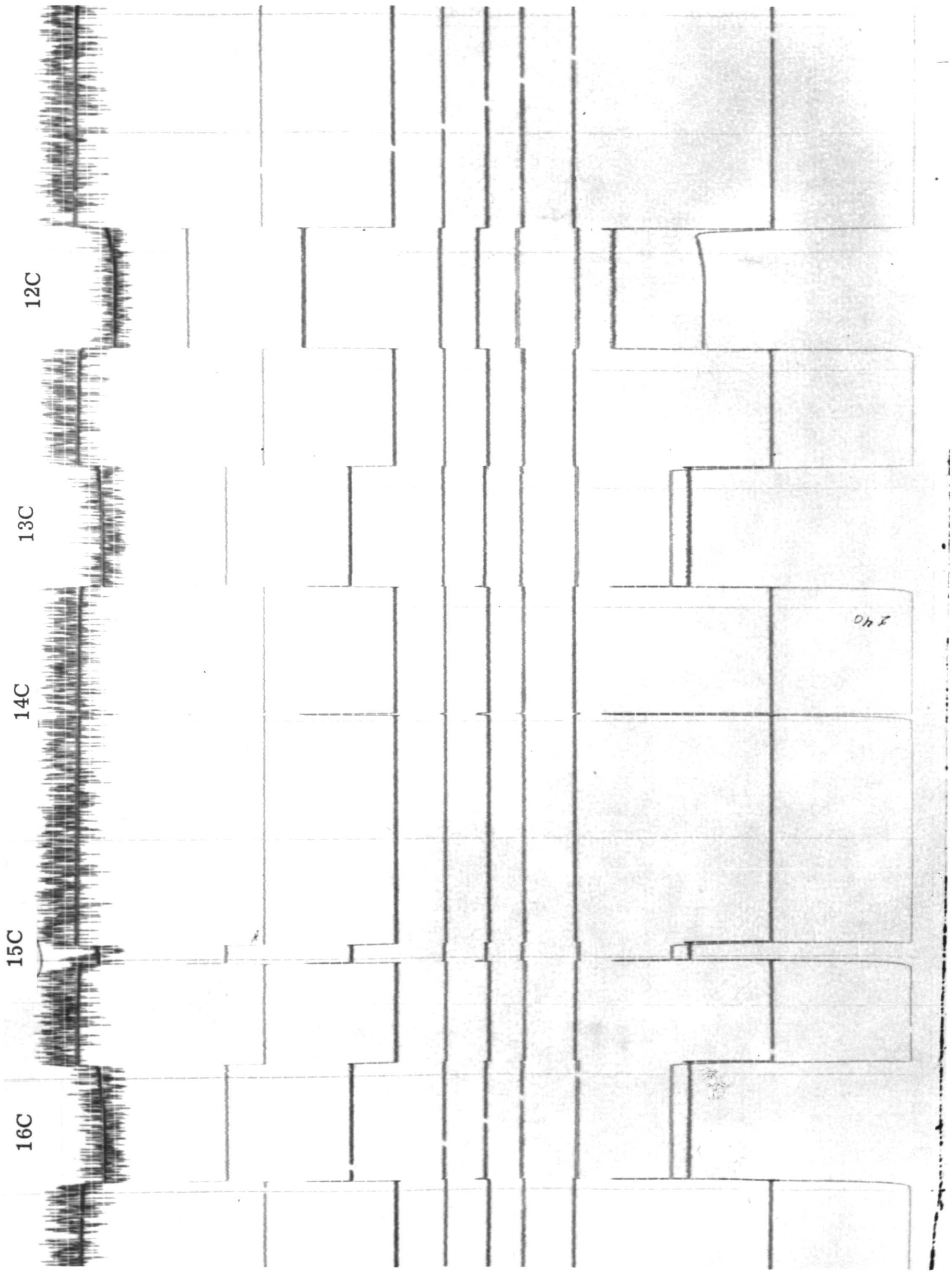
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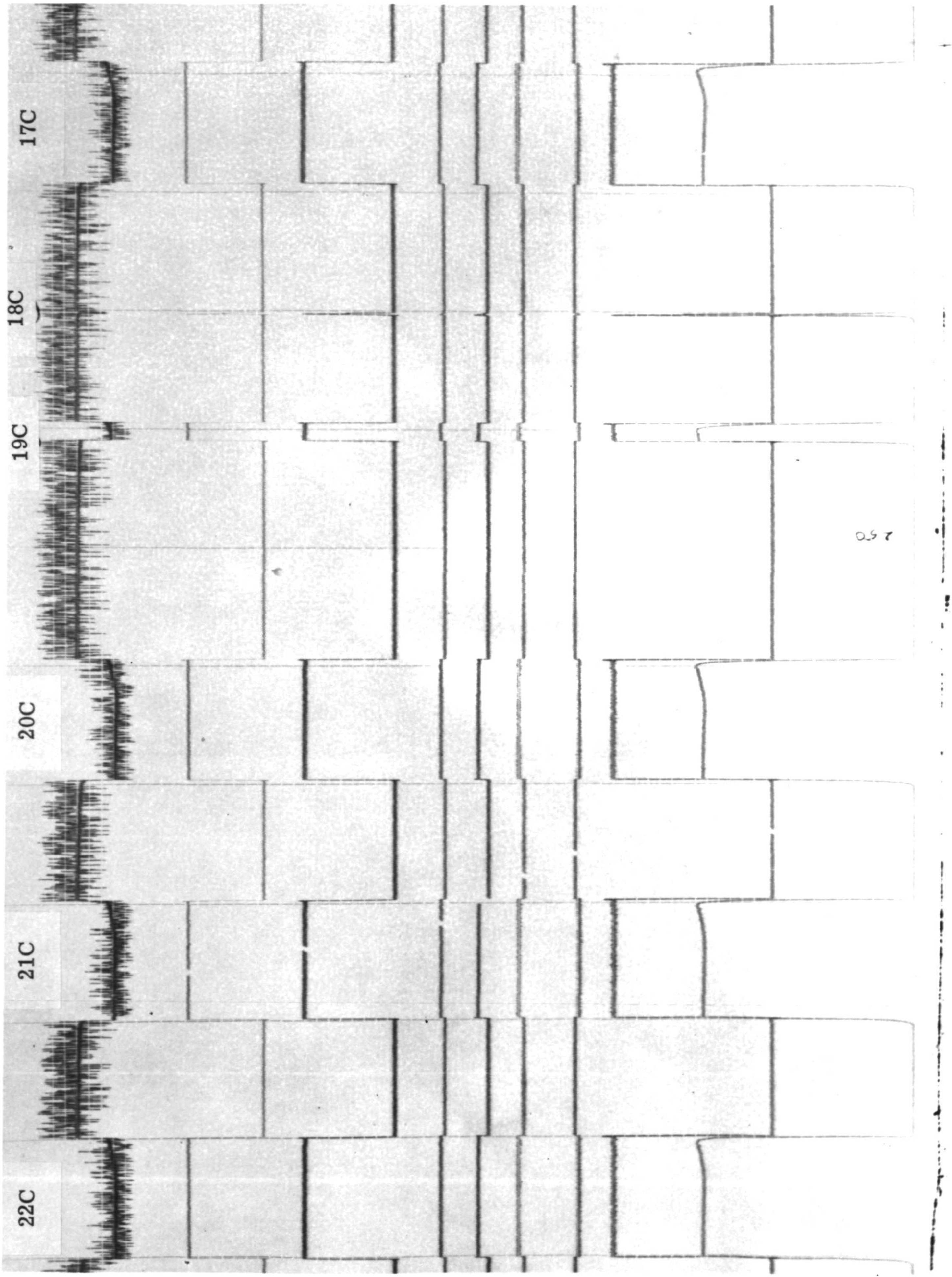
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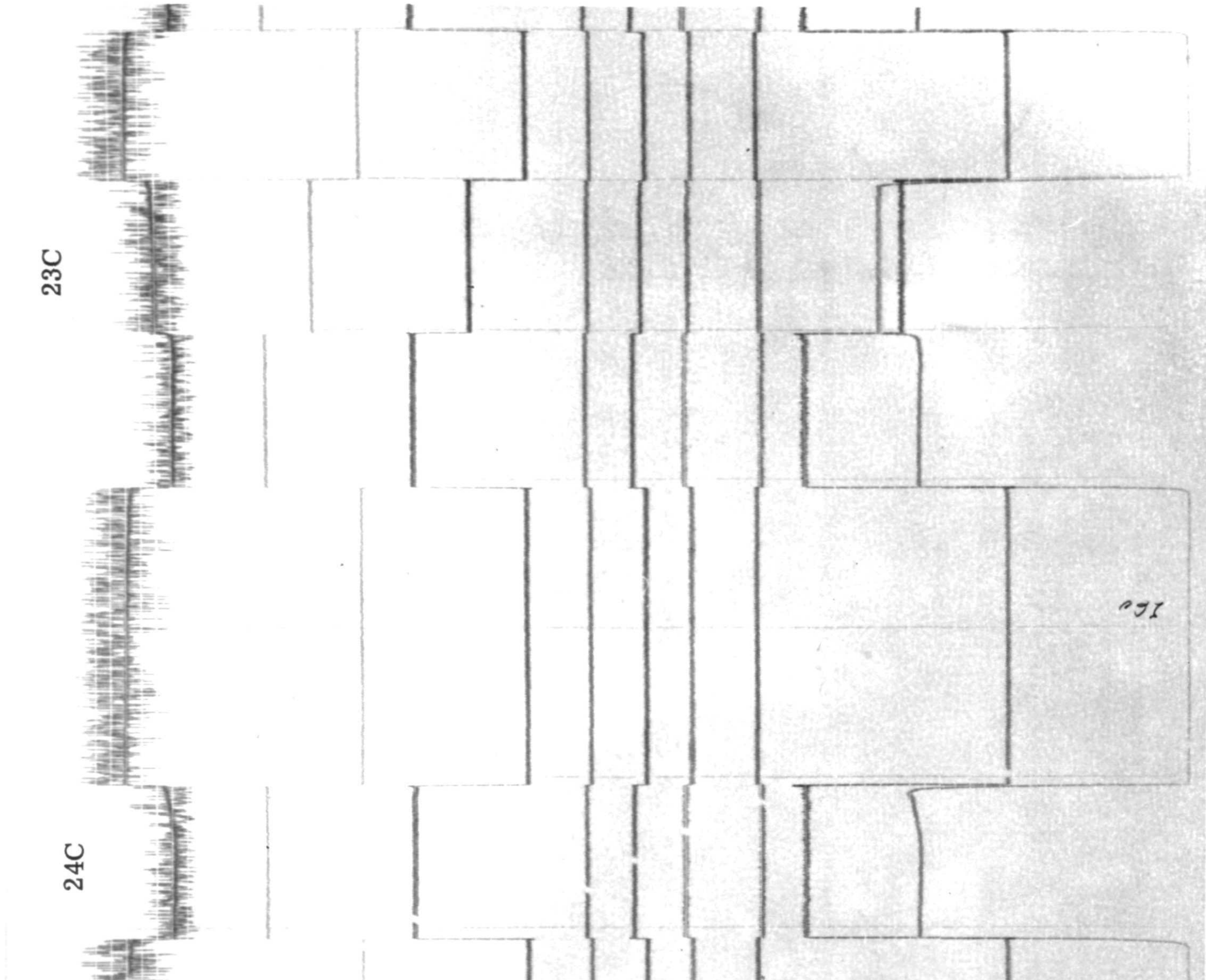
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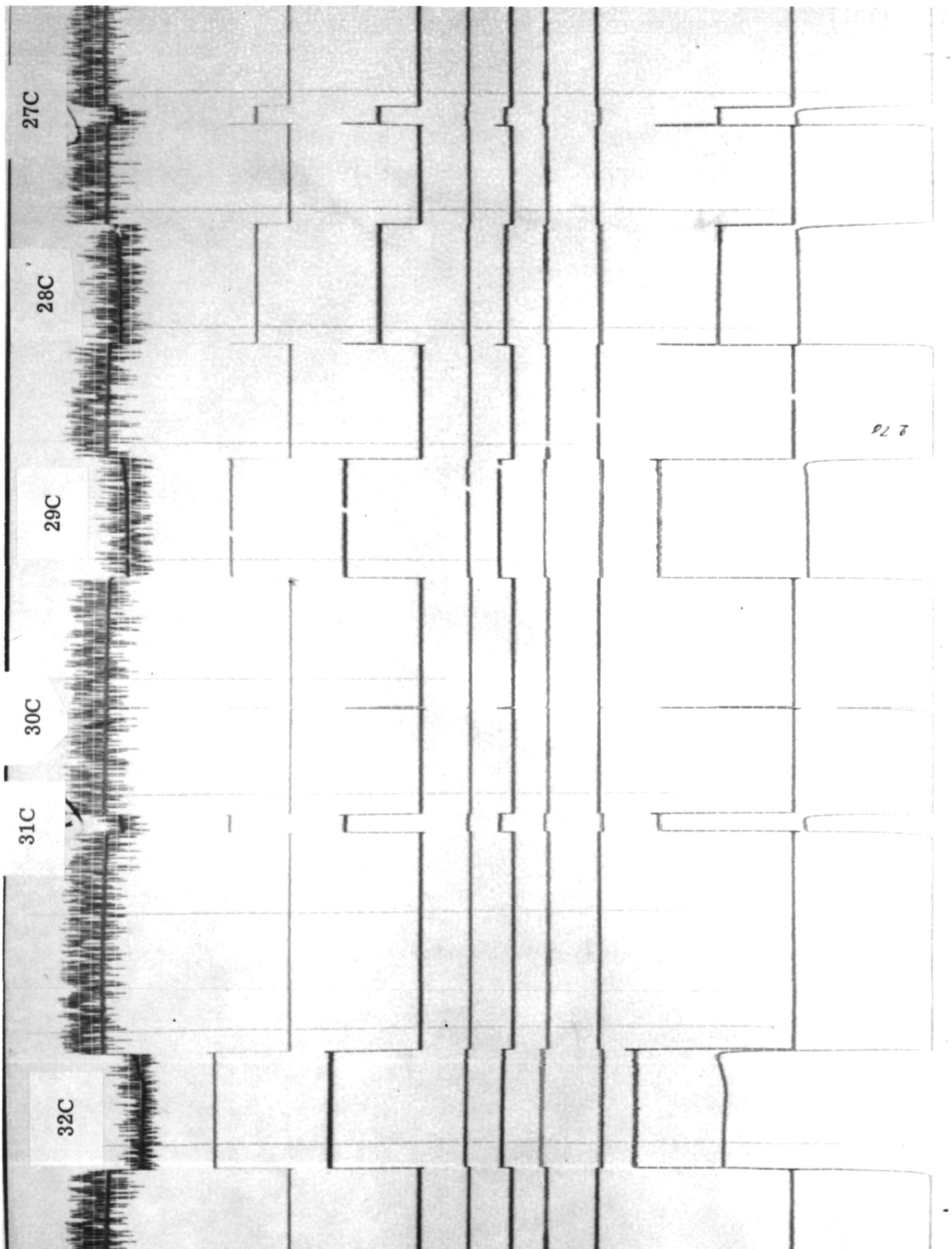
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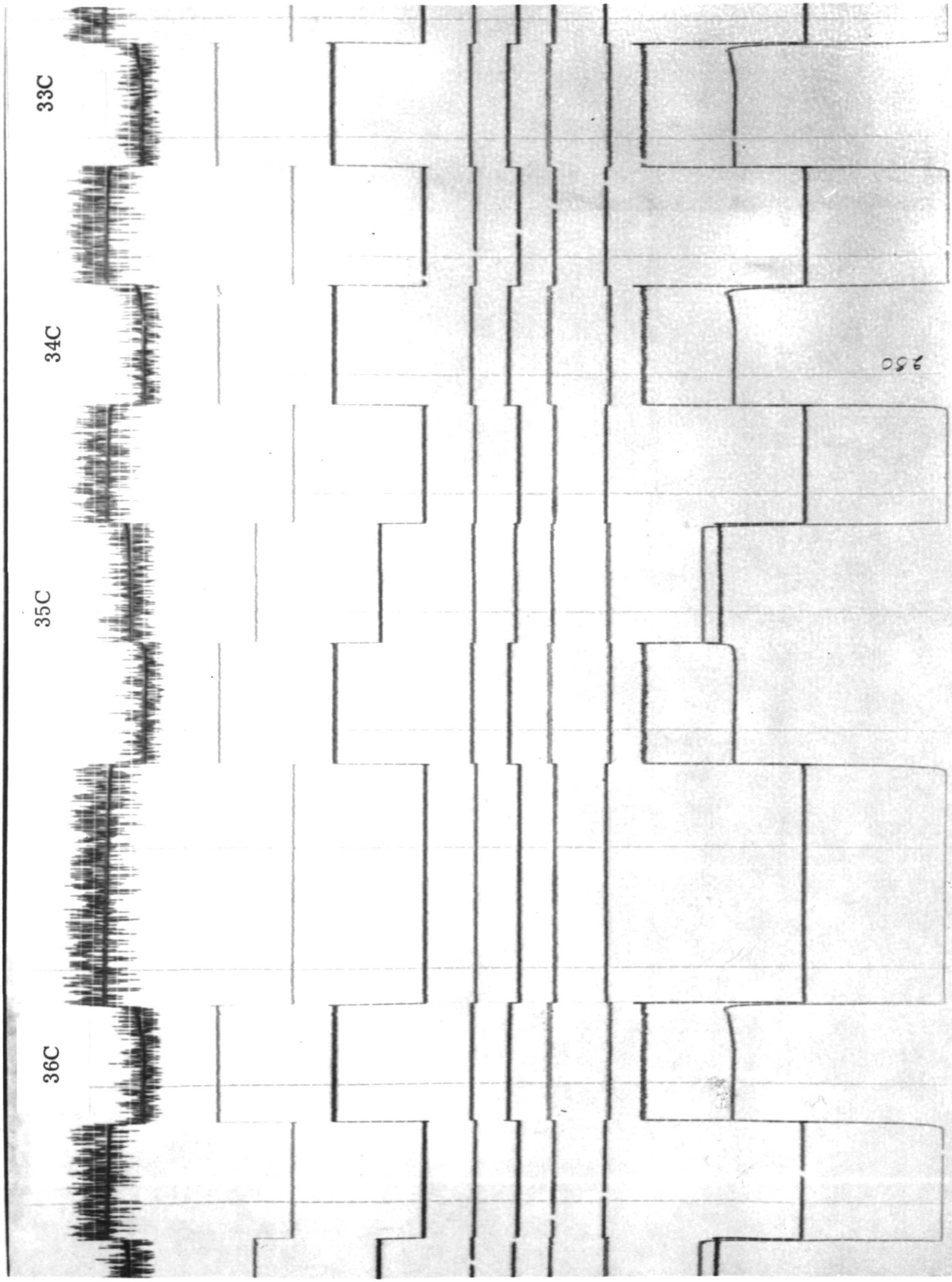
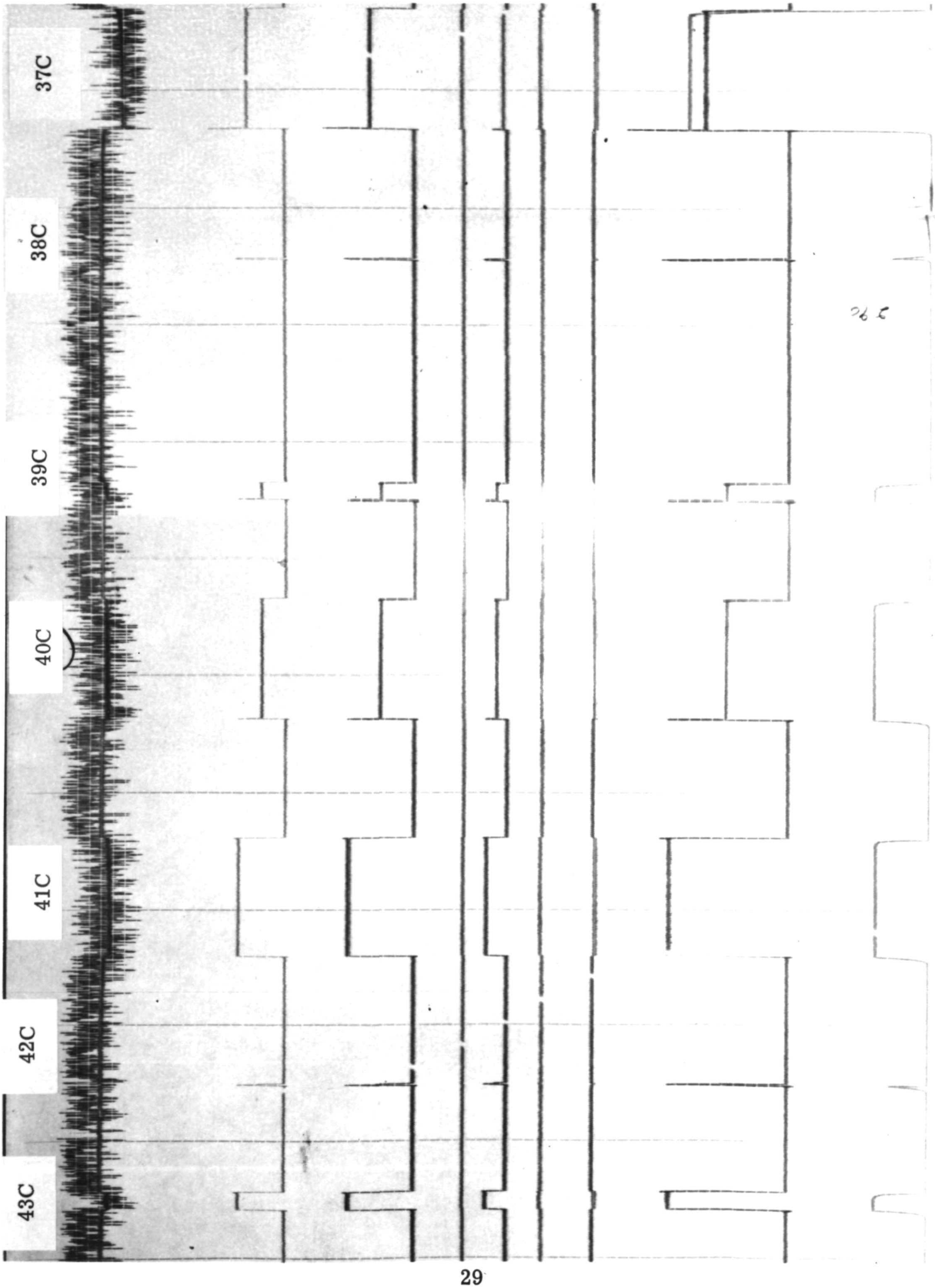
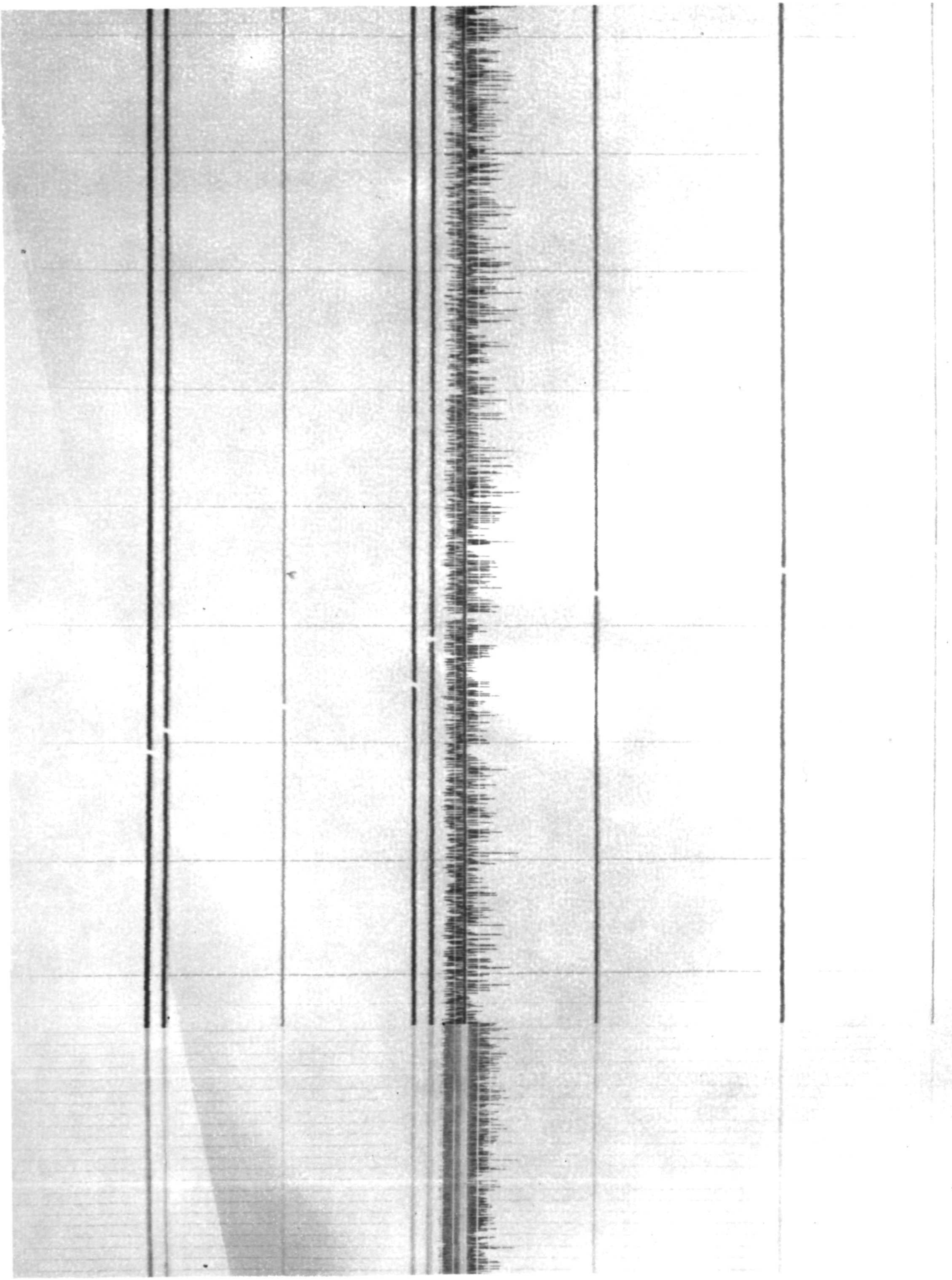
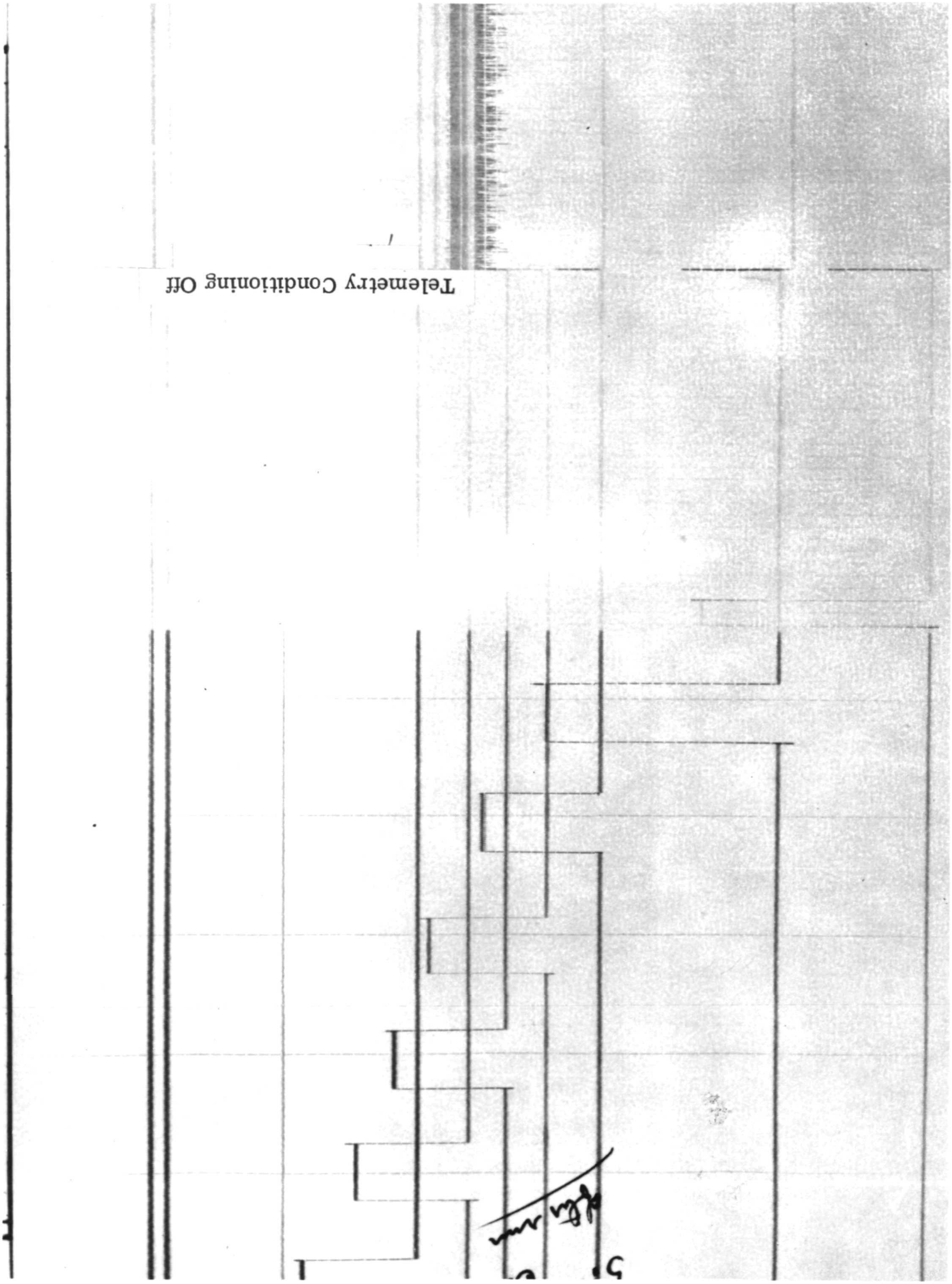
31C
32C

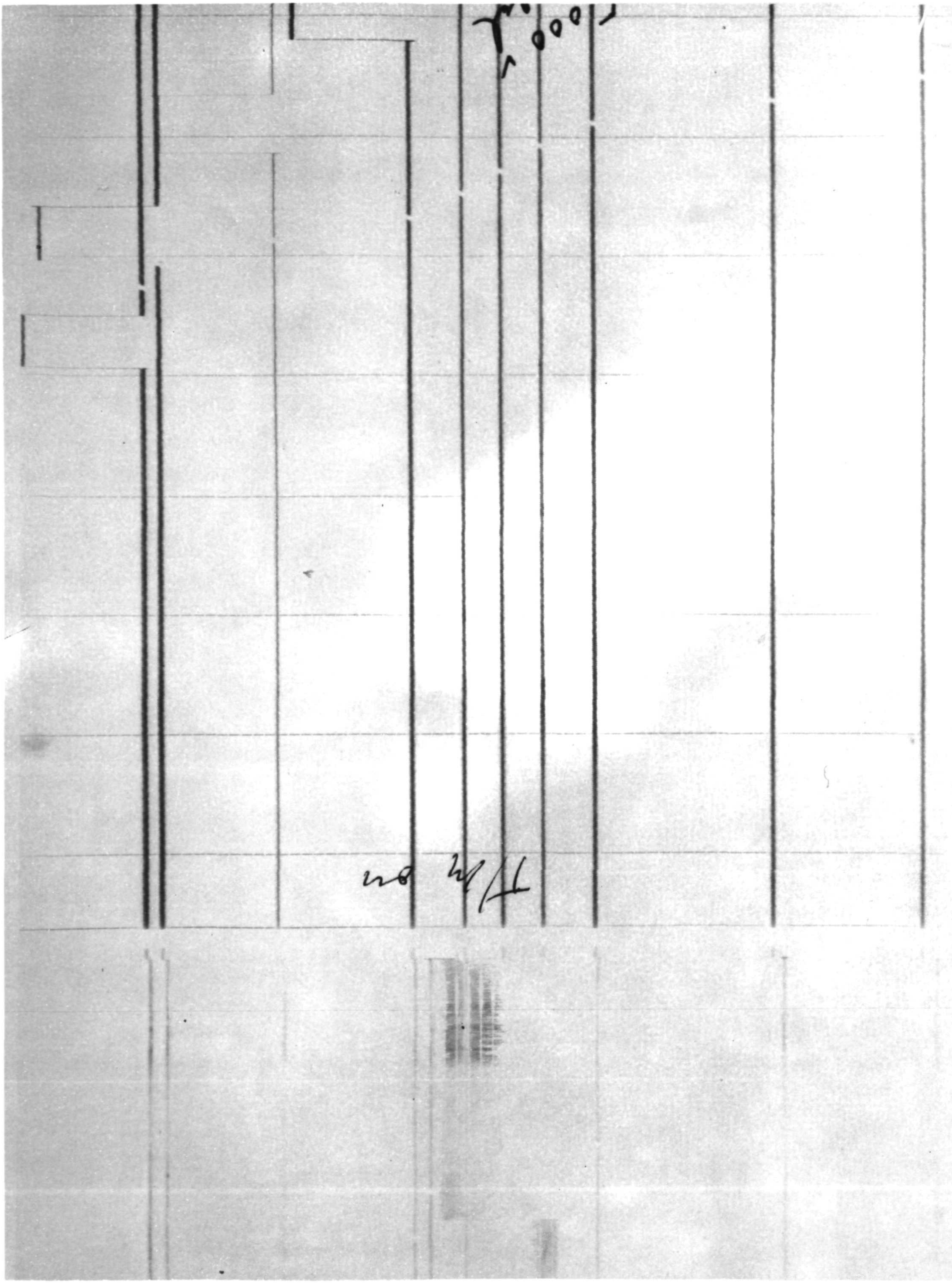

33C
34C
35C
36C


37C
38C
39C
40C
41C
42C
43C


44C
1D
2D
Turn Off
300
301
302
303
304




Telemetry Conditioning Off



Battery un plugged

APPENDIX B

ENVIRONMENTAL TESTING

APPENDIX B

ENVIRONMENTAL TESTING

In order to produce a payload with a high probability of success a methodical program of environmental testing was instituted. The program was designed to test subsystems which were developed as part of payload as they became available.

In addition to subsystem testing, a non-operated test of the entire system was performed.

Basically the subsystems tested on a qualification bases were:

(1) Electron Guns
(2) Batteries
(3) Payload Structure

Once the subsystems had been qualified, the entire payload was tested to flight levels. Figure B-1 shows the payload on the shake table during a resonant search.

The testing performed prior to payload shipment was intended to uncover any potential problems.

The final environmental tests would be conducted at Goddard Space Flight Center in the final flight configuration.

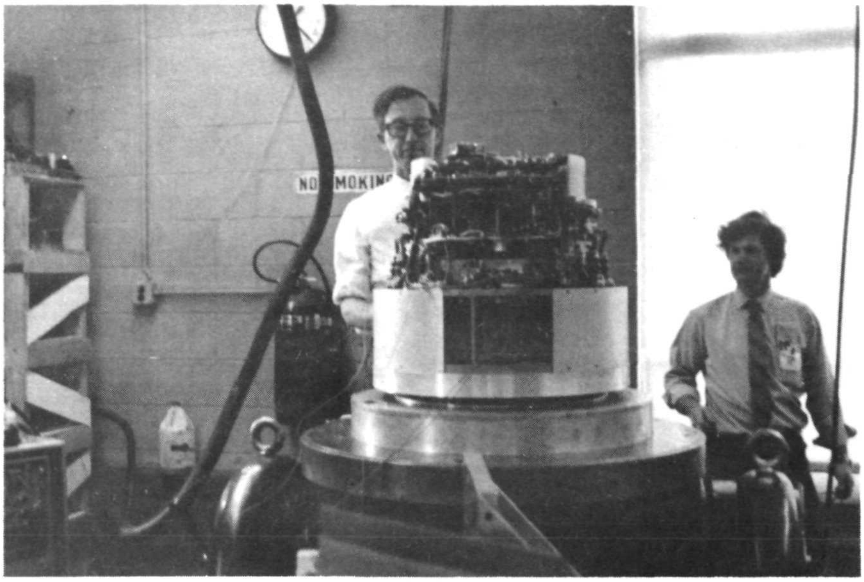


Figure B-1. Payload Testing.

Test Report No. NT-8839-11 No. of Pages 4

Contract #NAS-9-10399

Report of Test on

ROCKET PAYLOAD

Vibration Test

for

Ion Physics Corporation

Associated Testing Laboratories, Inc.

Date May 17, 1972

	Prepared	Checked	Approved
By	E. R. Mencow	M. Pelissier	E. E. Kulcsar
Signed	E. R. Mencow	M. Pelissier	E. E. Kulcsar
Date	5/19/72	5.23.72	5-24-72

Surveillance by: [illegible] Madison

DCRB-QDN 5/24/72

Administrative Data

1.0 Purpose of Test:

To evaluate the performance of the Rocket Payload when subjected to Vibration Testing in accordance with the referenced Specification and Procedures of this Test Report.

2.0 Manufacturer: Ion Physics Corporation
South Bedford Street
Burlington, Massachusetts 01803

3.0 Manufacturer's Type or Model No.: NASA Payload

4.0 Drawing, Specification or Exhibit: Vibration Test Specifications for Rocket Payload.

5.0 Quantity of Items Tested: One (1)

6.0 Security Classification of Items: Unclassified

7.0 Date Test Completed: April 24, 1972

8.0 Test Conducted By: Associated Testing Laboratories, Inc.

9.0 Disposition of Specimens: Returned to Ion Physics Corporation.

10.0 Abstract:

The submitted Rocket Payload was subjected to Sinusoidal Vibration over the frequency range of 10 to 2000 Hz at levels up to ±6g's peak. The unit was vibrated in three mutually perpendicular axes. There was one sweep up from 10 to 2000 Hz in each axis. There was no visible damage incurred to the unit as a result of the Sinusoidal Vibration Test. The unit performed satisfactorily as reported by Ion Physics Corporation.

TEST PROCEDURE

The submitted Rocket Payload was subjected to a Sinusoidal Vibration Test in accordance with Vibration Test Specifications for Rocket Payload. The following is a description of the test as it was performed.

The unit was securely attached to its Vibration Test fixture which, in turn, was attached to the table of the Vibrator. The unit was then subjected to Sinusoidal Vibration over the frequency range of 10 to 2000 Hz at the levels given below:

Table I

Frequency (Hz)	Amplitude
10 - 500	±1g
500 - 2000	±6g's

The frequency range from 10 to 500 Hz was swept up in approximately 30 seconds and the frequency range from 500 to 2000 Hz was swept up in approximately 30 seconds. There was no return sweep.

The above Procedure was performed in each of the unit's three mutually perpendicular axes. The Rocket Payload was examined for damage after vibration in each axis. The unit was in an operational mode during each sweep.

The unit was also subjected to a resonance search in the thrust axis only. The resonance search was performed at an input vibration level of 0.5g over the frequency range of 10 to 2000 Hz. Four Accelerometers were mounted inside the unit at locations specified by Ion Physics Corporation. The outputs of these accelerometers were recorded on an Oscillograph.

LIST OF APPARATUS

Item	Manufacturer	Model No.	Accuracy	Calibration Date	Calibration Date Due
Vibration System	Ling Electronics	335	Freq.±2% Ampl.±5%	3/3/72	6/3/72
Accelerometer	Endevco Corporation	2226	±5%	2/2/72	5/2/72
Accelerometer	Endevco Corporation	2226	±5%	2/3/72	5/3/72
Accelerometer	Endevco Corporation	2229C	±5%	4/3/72	7/3/72
Accelerometer			±5%	4/3/72	7/3/72
Accelerometer	Endevco Corporation	2271A	±5%	3/7/72	6/7/72
6 Channel Charge Amplifier	Unholtz-Dickie	11MGS	±1%	1/11/72	4/11/72
Vibration Meter	MB Electronics	M3	±2%	3/7/72	6/7/72
Vibration Pick-Up	MB Manufacturing Co.	115	N/A	N/A	N/A
Oscillograph	Honeywell	906B1	N/A	Prior to Use	
Oscillograph	Honeywell	906B	N/A	Prior to Use	

TEST RESULTS

There was no visible damage incurred to the Rocket Payload as a result of the Sinusoidal Vibration Test. The Oscillograph recordings of the resonance search in the thrust axis were retained by Ion Physics Corporation. The unit operated satisfactorily as reported by Ion Physics Corporation.

APPENDIX C

QUALIFICATION TEST REPORT

QTR-118

Qualification Test Report
for
Eagle-Picher Battery MAR 4428 & MAR 4428-3

Original

1 April 1971

EAGLE-PICHER INDUSTRIES, INC.
Electronics Division
Couples Department
Joplin, Missouri

TABLE OF CONTENTS

SUMMARY

On March 10-12, 1971 one MAR 4428-3 battery S/N 1 was subjected to electrical performance testing per QTP-151, Rev. A. The unit met all voltage and capacity requirements. The capacity provided after preload was 12.77 A.H.

After completion of the discharge test the unit was vibrated to the following levels to verify the cover seal.

Frequency - 20-2,000 Hz

Test Duration - 10 sec/axis

PSD Level - 0.05 g^2/cps

Acceleration - 10.0 grms

There was no physical degradation of the container or seal visible during or after completion of the test.

1.0 Scope

1.1 Purpose

This document presents the results of the Qualification Test Program, on a wet secondary battery, Eagle-Picher part number MAR 4428 or MAR 4428-3.

1.1.1 Qualification Testing

One (1) battery was subjected to qualification testing.

1.1.1.1 Requirements

During qualification testing one battery was subjected to bench test for capacity and voltage.

1.2 Definitions

1.2.1 Ion Physics

Ion Physics is Ion Physics Corporation, Burlington, Massachusetts, a subsidiary of High Voltage Engineering Corporation.

1.2.2 Eagle-Picher

Eagle-Picher is Eagle-Picher Industries, Inc., Electronics Division, Couples Department, Joplin, Missouri.

1.2.3 Test Specimen

Test specimen was the MAR 4428-3 battery.

1.3 General Notes

1.3.1 A record of all pertinent voltages, currents, times, temperatures, and pressures was recorded during the test. These records are included in this test report.

1.4 Applicable Documents

A. ACT-151, Activation and Operating Instructions for Battery, Silver-Zinc, MAR 4428 and MAR 4428-3

B. ATP-248, Acceptance Test Procedure

1.5 Test Conditions

1.5.1 Environmental Conditions

Unless otherwise specified, all tests required by this procedure were made at local ambient atmospheric conditions.

1.5.2 Measurement Error

The maximum allowable error over the range required for measurement systems used for tests in this report were as follows:

Temperature: ±2°F	Pressure: ±2%
Voltage: ±0.5%	Amperage: ±0.5%

1.6 Electrical Requirements

1.6.1 Activation

The specimen was activated and conditioned in accordance with Eagle-Picher Procedure ACT-151. The time activation was started and completed was recorded. The unactivated and activated weight of the specimen was also recorded. The open circuit voltage met the requirements of ACT-151.

1.6.2 Electrical Loads

The specimen was discharged through the following loads as specified:

Circuit	Load	Nominal Load Voltage
Tapped Circuit	185 amperes	15 VDC
Full Circuit	50 amperes 100 amperes 150 amperes	50 VDC

1.6.3 Capacity

The specimen was required to deliver a minimum capacity in excess of 7 ampere-hours when discharged to the loads of paragraph 1.6.2.

1.6.4 Load Application

The steady state load application was made using a variable resistor. Application of pulse loads were made through a preset resistive load.

1.6.5 Temperature Sensor

During the test described herein the resistance of the temperature sensor was measured. The temperature corresponding to the resistance value was determined from the temperature vs. resistance curve of Figure 1 and the temperature recorded on the data sheet. Thermistor measurements were made through pins W and V of J2 connector.

1.6.6 Pressure Transducer

During the test described herein the output voltage of the pressure transducer was measured. The pressure corresponding to the voltage value was determined from the pressure vs. voltage curve of Figure 2, and the pressure recorded on the data sheet. Pressure transducer measurements were made through pins U and T of J2 connector.

2.0 Examination of Product

The specimen was subjected to and passed the tests and inspections of ATP-248 before start of the test described herein.

3.0 Performance Test

3.1 Requirements

The specimen was discharged to demonstrate compliance with the requirements of paragraphs 1.6.2 and 1.6.3.

3.2 Procedure

The activated specimen was discharged as follows:

Prior to beginning discharge a vacuum line was connected to the pressurizing port of the battery and the internal pressure evacuated to 5.0 lb/in^2 absolute. After evacuation the pressurizing port was

3.2 Procedure (Continued)

closed off and the vacuum line disconnected. The activated specimen was then discharged as follows:

Connector Pins	Discharge Rate
J1 - V, W, X, J2 - A, B, C, D, E, F, G, H, K, L, to J1 - A, B, C, D, E, F, G, H, J	185 amperes for 4 seconds
J1 - A, B, C, D, E, F, G, H, J, to J1 - K, L, M, N, P, R, S, T, U	

1) 100 amps 1 sec.* followed by OCV approximately 2 seconds then 100 amps for 6 seconds

2) Place battery in 113 ± 5°F chamber and immediately begin discharge as follows:

   a) 50 amps for 1 sec. followed by OCV approximately 2 sec. then 50 amps for 6 sec.

   b) 150 amps for 1 sec. followed by OCV approximately 2 sec. then 150 amps for 6 sec.

   c) 100 amps for 1 sec.* followed by OCV approximately 2 sec. then 100 amps for 6 sec.

   d) 100 amps for 6 sec. on, 6 sec. off, continue until voltage drops to 40.0 VDC

During the discharge the internal battery temperature and pressure were measured and recorded as specified in paragraph 1.6.5 and 1.6.6. During the discharge the battery terminal voltage and output current were recorded continuously.

3.3 List of Equipment

Item	Manufacturer	Model
Voltmeter	Weston	931
Ammeter	Weston	931
Resistance Bridge	Leeds-Northrup	4282
Recorder	C.E.C.	5-124
Timer	Standard	SM-60
Discharge Panel	EPI	N/A

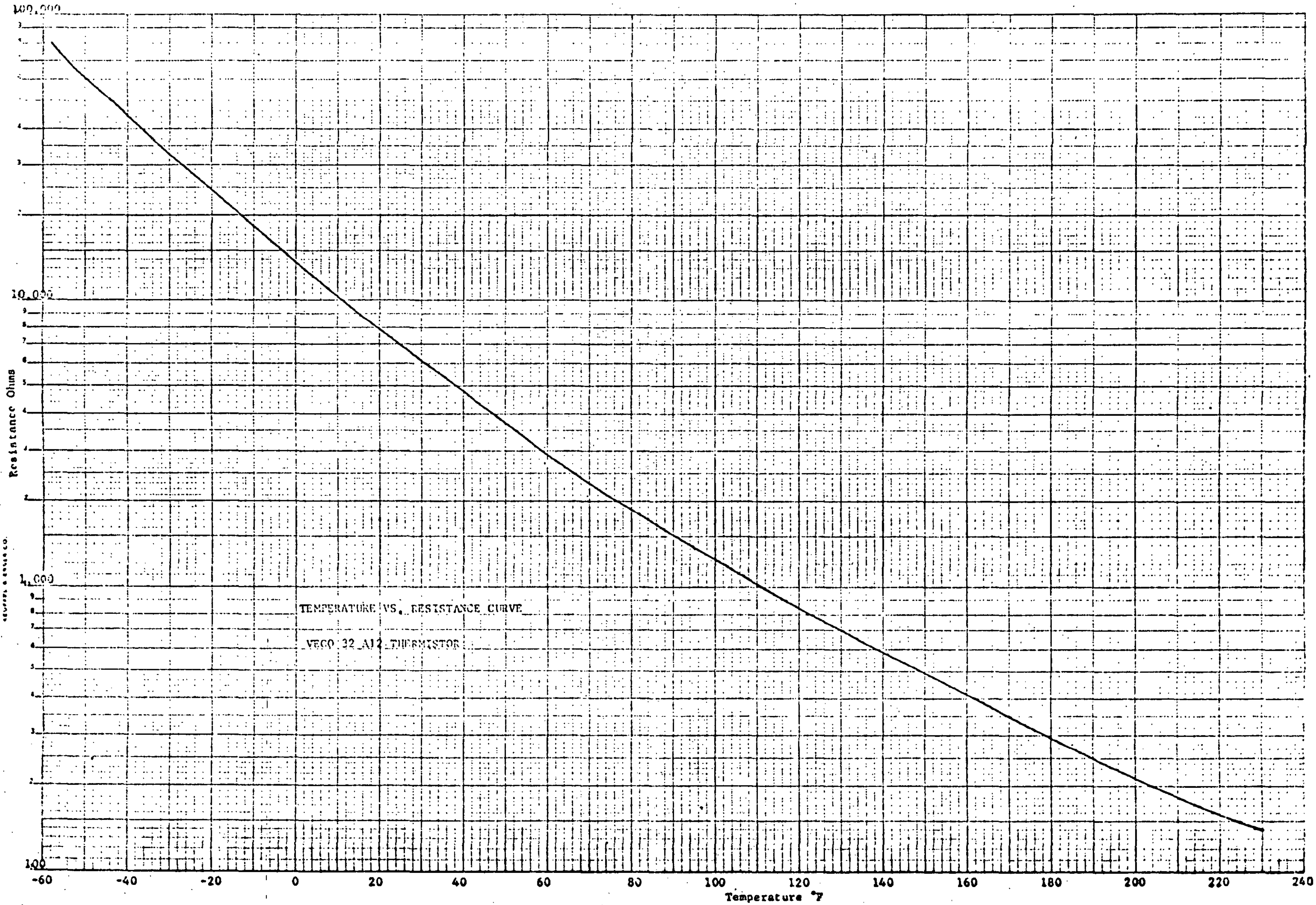
*Obtain a scope picture of voltage drop this surge.

4.0 Test Sequence

4.1 Examination - Ref. para. 2.0

4.2 Activation - Ref. para. 1.6.1

4.3 Performance Test - Ref. para. 3.0



TEMPERATURE VS. RESISTANCE CURVE
VECO 32 A12 THERMISTOR
Resistance Ohms
100,000
10,000
1,000
100
Temperature °F
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
200
220
240

Figure 1

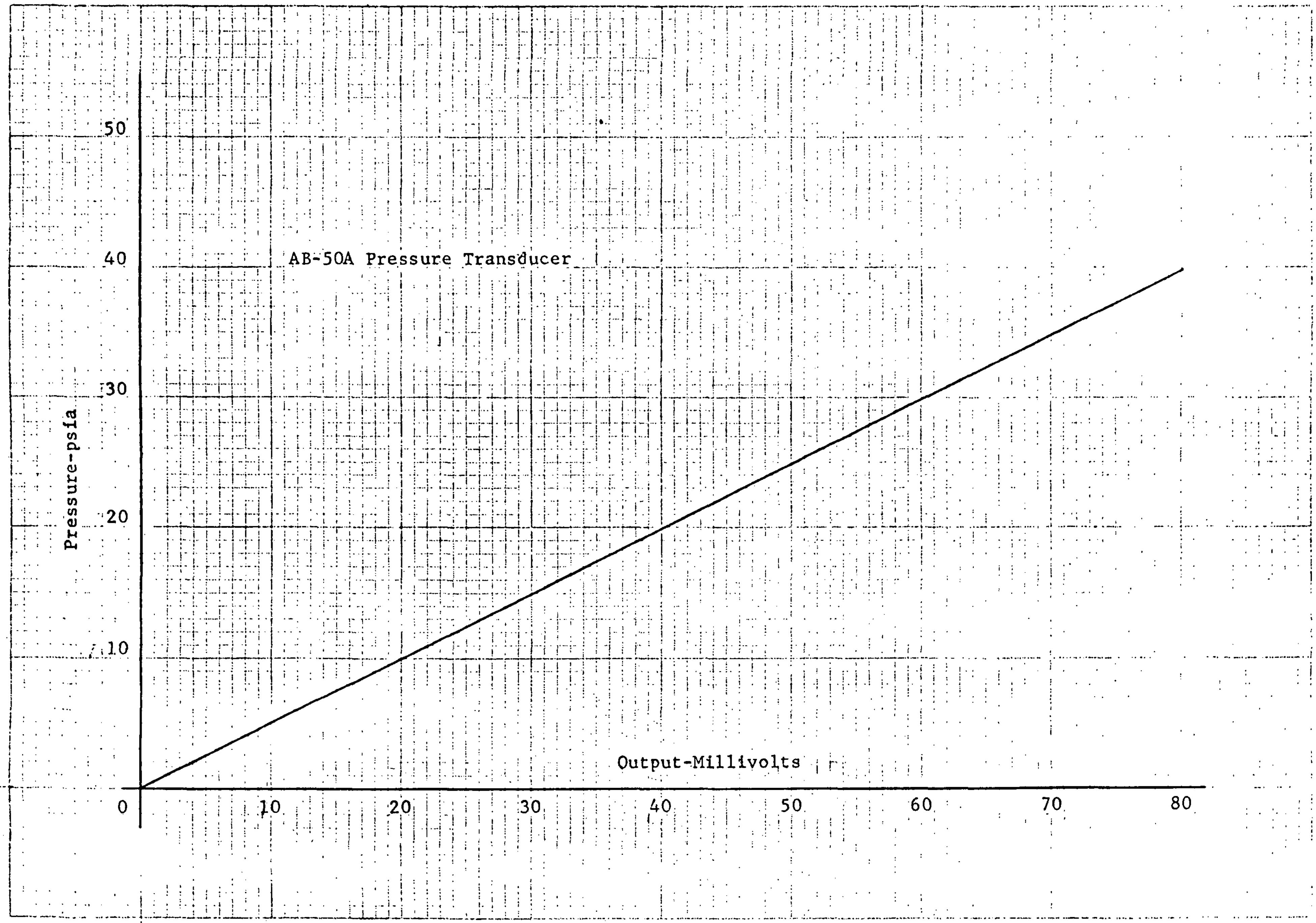

AB-50A Pressure Transducer
Pressure-psia
50
40
30
20
10
0
10
20
30
40
50
60
70
80
Output-Millivolts

Figure 2

APPENDIX A

SUMMARY OF TEST RESULTS ON A BATTERY OF SIMILAR DESIGN

The following summary gives the environments imposed on E-P cell number 004569 which utilizes the same construction as the Ion Physics cell but is slightly smaller in size. In addition to this test data, one prototype battery MAR 4428 was fabricated and tested to the expected dynamic levels with no damage or degradation of performance. These test results are presented in E-P letter report 25 September 1970, Hailey to Weinschenk and IPC memorandum, 21 October 1970, Weinschenk to Hansen.

Shock

Twenty-one of the 004569 cells were assembled in a stainless steel container fabricated in the same manner as the 4428 battery and subjected to a complex wave excitation shock of 2400 g peak. The units were shocked three times in each direction of the three orthogonal axes for a total of 18 shocks. There was no evidence of damage from this test.

Vibration

The above battery assembly was subjected to 23.7 grms (.45 g^2/cps) vibration for 180 seconds in each of three orthogonal axes. There was no evidence of damage from this test. In addition the bench test battery (MAR 4428-3, S/N 1) was vibrated to the required spectrum with no damage.

Temperature Shock

The 004569 cell design was subjected to 35 days stand at 90°F. A total of 300 cells were tested with no failures. Approximately half of these cells were assembled in 21 cell batteries and half were tested in 5 cell groups.

Pressure

The above batteries were tested with a pressure drop from ambient to 200,000 feet in 7-10 minutes and maintained at this altitude for 10 minutes. A large number of other battery designs with the same cell sealing and venting and the same container sealing and venting design have passed altitude tests of up to one week at 10^{-6} mm Hg and have operated for several weeks in space.

APPENDIX B

TEST RESULTS

THE EAGLE-PICHER COMPANY

Couples Dept. Joplin, Missouri

TEST PROCEDURE NO. ______ DATE 3-10-71

TEST PARA. NO ______ E. P. BAT. TYPE 4428-3

AMBIENT T. ______ F

TYPE PROGRAM

UNACTIVATED WEIGHT 31.90 lb

ACTIVATE IN ACCORDANCE WITH EAGLE-PICHER ACTIVATION PROCEDURES ACT- 151

TIME STARTED 10:30 TIME COMPLETED 11:16

ACTIVATED WEIGHT 36.95 lb

CC's KOH PER CELL 42 SP. GR. OF KOH 1.400

CELL OPEN CIRCUIT VOLTAGE

Cell No.	O.C.V.	Cell No.	O.C.V.
1	1.85	22	1.85
2	1.85	23	1.85
3	1.85	24	1.85
4	1.85	25	1.85
5	1.85	26	1.85
6	1.85	27	1.85
7	1.85	28	1.85
8	1.85	29	1.85
9	1.85	30	1.85
10	1.85	31	1.85
11	1.85	32	1.85
12	1.85	33	1.85
13	1.85	34	1.85
14	1.85	35	1.85
15	1.85	36	1.85
16	1.85	37	1.83
17	1.85	38	1.83
18	1.85	39	1.83
19	1.[illegible]		
20	1.85		
21	1.85		

BATTERY O.C.V. 72.2 VDC

REMARKS:

	Voltmeter
TYPE	Weston
MODEL	931
S/N	37743
CALIB. FACTOR	1=1.003
CALIB. DUE DATE	3-18-71
OPERATOR	[illegible]
ENGINEER	
INSPECTOR	

TF-60

EAGLE PICHER INDUSTRIES, INC.
Couples Plant - Joplin, Missouri

TEST SPEC [illegible] NO. 1

DATE 3-11-71 — 1312

BATT. TEMP. 87 F

TYPE PROGRAM: [illegible]

PREVIOUS TEST [illegible]

[illegible] charge at 14 amps for 45 minutes

TIME	VOLTS	AMPS	Res.	mv.	Temp°F	Press	VOLTS	AMPS
[illegible]	71.64	0	1615	12.5	87	6.2		
[illegible]	58.69	14						
[illegible] min	58.79			12.5		6.2		
5 [illegible]	58.83		1452	12.9	93	6.4		
10 [illegible]	59.05		1315	13.9	97	6.9		
20 [illegible]	59.31		1101	15.6	106	7.3		
30 min	59.45		930	17.2	115	8.5		
45 min	59.65	14	894	18.3	117	9.1		

	Voltmeter	Ammeter
TYPE	Weston	Weston
MODEL	4000	1
S/N	112	279[illegible]
CALIB. FACTOR	1.05%	150 = [illegible]
CALIB. DUE DATE	3-18-71	4-6-71
OPERATOR		
ENGINEER		
INSPECTOR		

EAGLE-PICHER INDUSTRIES, INC.
Couples Plant - Joplin, Missouri

TYPE TEST: Discharge — TEST SPECIMEN NO 1

TEST PROCEDURE NO. (QTP-151) — DATE 3-12-71 — TIME 1345
TEST P. R.A. REF NO. 3.8 — E. P. BAT. TYPE [illegible] 4428 — S. N. 1
AMBIENT TEMP. ____ F — ION-PHYSICS BAT. NO. ____
BATT. TEMP. ____ °F — TYPE PROGRAM: PROD ☐ QUAL. ☒ R & D ☐
PREVIOUS TEST: ____

Load 15 V tap at 180 amperes for 4 seconds

TIME	VOLTS	AMPS	Res	MV	Temp °F	Press	VOLTS	AMPS
OCV	20.97	0	1927	13.7	78	6.8		
100 ms	15.90	173						
500 ms	15.95							
1 sec	16.0							
2 sec	16.0							
3 sec	16.0							
4 sec	16.0		1860	13.7	80	6.8		

	Voltmeter	Ammeter
TYPE	Weston	Weston
MODEL	4000	1
S/N	112	27940
CALIB. FACTOR	1.0596	180 = 178.4
CALIB. DUE DATE	3-19-71	4-6-71
OPERATOR		
ENGINEER		
INSPECTOR		

TF-41 WHITAKER PTG

EAGLE-PICHER INDUSTRIES, INC.

Couples Plant · Joplin, Missouri

TYPE TEST: Discharge TEST SPECIMEN NO. 1

TEST PROCEDURE NO QTP-151 DATE 3-12-71 TIME

TEST PARA. REF. NO. 5.0 E. P. BAT. TYPE MAR 4445-3 S. N. 1

AMBIENT TEMP °F Ion-Physics BAT. NO.

BATT. TEMP. 81 °F TYPE PROGRAM: PROD ☐ QUAL XX R & D ☐

PREVIOUS TEST

1. 100 A for 1 sec. followed by approx. 2 sec. at OCV, then 100 A for 6 sec.
2. Place battery @+113 ± 5°F and discharge (a) 50 A for 1 sec. followed by 2 sec. @ OCV, then 50 A for 6 sec. (b) 150 A for 1 sec. followed by approx. 2 sec. OCV, then 150 A for 6 sec. (c) 100 A for 1 sec. followed by approx. 2 sec. OCV, then 100 A for 6 sec. (d) 100 A for 6 sec. on, 6 sec. off, continued to 40.0 VDC.

	TIME	VOLTS	AMPS	TEMP.	PRESS.
	OCV	62.5	0	1515	13.0
	1st Pulse			81°F	6.8 psia
	100 ms	51.5	103		
	500 "	51.9	105		
	1 sec.	52.0	104		
	2nd Pulse				
	100 ms	52.0	104		
	500 "	52.0	103		
	1 sec.	52.0	102		
	2 "	52.0	102		
	4 "	52.0	102		
	6 "	52.0	102	1760	13.3
		62.78		82°F	6.8 psia
a	1st Pulse			1743	14.0
	100 ms	57.3	51.0	83°F	7.0 psia
	500 "	56.8	51.0		
	1 sec.	56.5	51.0		
	2nd Pulse				
	100 ms	57.0	51.0		
	500 "	56.4	51.0		
	1 sec.	56.4	51.0		
	2 "	56.2	51.0		
	4 "	56.1	52.0		
	6 "	56.0	52.0	1726	14.1
b	1st Pulse			1712	14.1
	100 ms	50.7	147	83°F	7.0 psia
	500 "	48.8	142		
	1 sec.	50.0	143		
	2nd Pulse				
	100 ms	50.0	143		
	500 "	50.0	143		
	1 sec.	50.0	143		
	2 "	50.0	143		
	4 "	50.0	141		
	6 "	[illegible]	141	1646	14.1
c	1st Pulse 60.01			1627	14.2
	100 ms	54.0	103	86°F	7.1 psia
	500 "	53.5	102		
	1 sec.	53.3	101		

TIME	VOLTS	AMPS	TEMP.	PRESS.
2nd Pulse	60.9			
100 ms	54.0	102		
500 "	53.3	100		
1 sec.	53.3	100		
2 "	53.3	100		
4 "	52.8	100		
6 "	52.7	100		
2d 1st Pulse	60.3	0	1627	14.2
100 ms	53.5	103	86°F	7.1 psia
500 "	52.5	102		
1 sec.	52.5	102		
2 "	52.5	102		
4 "	52.2	103		
6 "	52.1	103		
2nd Pulse	60.3	0		
100 ms	53.2	107		
500 "	52.2	104		
1 sec.	52.1	104		
2 "	52.1	103		
4 "	52.0	103		
6 "	52.0	103		
10th Pulse	59.9	0		
100 ms	53.3	107		
500 "	51.6	103		
1 sec.	51.7	102		
2 "	51.7	102		
4 "	51.7	102		
6 "	51.7	102		
15th Pulse			2330	14.4
			101°F	7.3 psia

	Voltmeter	Ammeter
TYPE	Weston	Weston
MODEL	4000	1
S N	112	27760
CALIB. FACTOR	±.05%	150=14
CALIB. DUE DATE	3-18-71	4-6-71
OPERATOR		
ENGINEER		
INSPECTOR		

TF-41 WHITEHEAD PTG

EAGLE-PICHER INDUSTRIES, INC.
Couples Plant · Joplin, Missouri

TYPE TEST: Discharge — TEST SPECIMEN NO. 1

TEST PROCEDURE NO. QTP-151 — DATE 3-12-71 — TIME

TEST PARA. REF. NO. 3.0 — E. P. BAT. TYPE MAR 4428-5 S. N. 1

AMBIENT TEMP. F — Ion-Physics BAT. NO.

BATT. TEMP. 116 °F — TYPE PROGRAM: PROD ☐ QUAL. ☒ R & D ☐

PREVIOUS TEST:

TIME	VOLTS	AMPS	TEMP.	PRESS.
20th Pulse	57.7	0		
100 ms	53.9	105		
500 "	53.2	103		
1 sec.	52.2	100		
2 "	52.2	100		
4 "	52.3	100		
6 "	52.3	100		
30th Pulse	57.8	0 -\- 900 =	14.9 = @ 25th Pulse	
100 ms	54.8	105	116 °F	7.4 psia
500 "	53.5	103		
1 sec.	52.7	101		
2 "	52.7	101		
4 "	52.9	101		
6 "	52.7	101		
40th Pulse	57.8	0	775 =	15.6 =
100 ms	54.6	105	124.5 °F	7.8 psia
500 "	53.9	103		
1 sec.	53.2	101		
2 "	53.3	101		
4 "	53.2	100		
6 "	53.2	100		
50th Pulse	57.8	0	650 =	16.4
100 ms	54.6	107	135 °F	8.2 psia
500 "	53.5	105		
1 sec.	52.5	102		
2 "	52.0	100		
4 "	51.6	100		
6 "	51.0	100		
60th Pulse	55.5	0	569 =	17.6
100 ms	53.2	110	141 °F	8.8 psia
500 "	51.2	105		
1 sec.	50.2	103		
2 "	49.8	102		
4 "	49.0	100		
6 "	48.3	99		
70th Pulse	51.5	0	478 =	21.3 =
100 ms	45.6	120	152 °F	10.6 psia
500 "	45.5	113		
1 sec.	44.1	109		
2 "	42.7	104		
4 "	40.2	100		

TIME	VOLTS	AMPS	TEMP.	PRESS.
6 sec.	38.5	100	437 =	24.6
			157 °F	12.2 psia

Capacity = 12.77 A.-

	Voltmeter	Ammeter
TYPE		
MODEL		
S N		
CALIB. FACTOR		
CALIB. DUE DATE		
OPERATOR		
ENGINEER		
INSPECTOR		

APPENDIX D

QUALITY ASSURANCE PROVISION FOR ACCEPTANCE TESTING OF ELECTRON GUNS, ELECTRON ACCELERATOR PACKAGE

Serial Number 30

Specification I/ML-EE65-1
Revision 3
Date 10/21/70

Quality Assurance Provision
for
Acceptance Testing
of
Electron Guns, Electron Accelerator Package

Contract NAS 9-10399
IPC WA - 89107

Prepared by W. E. Starks
Approved R. V. James
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ION PHYSICS CORPORATION IPC
A Subsidiary of High Voltage Engineering Corporation
BURLINGTON, MASSACHUSETTS

1.0 Scope

This procedure defines the acceptance tests to be performed on the Electron Guns, Electron Accelerator Package, in order to verify the operating condition and quality of performance

2 0 Applicable Documents

The following documents are applicable to the equipment for which the tests described in this procedure are intended:

IPC Drawing Numbers

C - 1055-002 (sheets one and two)

3.0 Test Requirements

3.1 General

These units will provide a 100 milliampere electron beam at a maximum energy of 20 KeV operating at a 33% duty cycle in output power for a minimum lifetime of 10 minutes. The ensuing tests will not involve testing units to these limits as destructive testing would be necessary to achieve this information.

3.2 Test Equipment

The following test equipment is required for the tests described in this procedure:

(1) Oscilloscope, Tektronix Model 536 with 2 IAI's or IA2's plugin units, or Tektronix Model 502A used X-Y.

(2) Camera, Tektronix Model C-19 or Tektronix Model C-27 with 3000 speed Polaroid Film (black & white).

(3) Power supply, Kepco Model ABC, 0-10 volts, 0-3 amps

(4) Power supply, Sorenson Model QRB 40-.75, 0-40 volts, 0-750 mA

(5) Picoammeter, Keithley Model 414

(6) Simpson Multimeter, Model 260-5M, or RCA model WV98C VTVM

(7) Hartman and Braun Wheatstone Bridge

(8) High voltage power supply, Del Electronics Model 25-200-1, 0-25KV, 0 - 200 mA or Del 25-50-1

(9) Power supply, Kepco Model ABC 0-1500V, 0-10 mA.

(10) 30V Ramp-generator B 1055-042

(11) High voltage power supply, Spellman Model RHR 50PN150, 0 to 60 KV, 0 to 5 mA

(12) EE-65-1 Test Fixture

(13) Fan for end cap aircooling

(14) Binocular Microscope or 3X magnifier

• This equipment must be maintained on a calibration cycle of once every six months or oftener.

3.3 Test Conditions

3.3.1 Environmental Conditions

Perform all inspection in semi-clean room when possible. In transporting tube to and from clean room, keep in a clean plastic bag and cardboard box to prevent exposure to general plant atmosphere. Handle only with lint free silk gloves or talc-free rubber finger cots.

Tests outlined in sections 6.0 and 7.0 shall be performed with the test unit mounted in item 10 of section 3.2 with the fixture contained in one (1) atmosphere of dry sulphur hexaflouride gas (SF_6).

3.3.2 Power Requirements

The following power sources are required for the tests described in this procedure:

(1) 115 Vac, ± 10%, 60 Hz, 0.5 KVA

(2) 208 Vac, 3ϕ, ± 10%, 60 Hz, 5 KVA

3.3.3 Test Sequence

All tests must be performed in the order in which they are given in this procedure.

4.0 Visual Inspection

Inspect each unit visually for defects in workmanship and handling. If there is any defect, enter the letter "R" (rejected) in the appropriate space below: if no defect, enter the letter "A" (accepted). In either case, the inspector must sign off the test record. Is the package sealed? (Yes or No) ______ ______

(date) (initial)

TEST DATA

	ITEM	A/R	Date	Initial
4.1	Breakseal Tabs-Inspect Brazing for any pull-away of tabs. Reject if tabs are not tight. Do not pull on tabs this is visual insp. only.	A	6/30/71	[illegible]
4.2	Breakseal Metalized Band-Inspect for pits, holes, or cracks with a binocular microscope.* Reject if any.	A	6/30/71	[illegible]
4.3	Anode two to cap ceramic. Inspect for cleanliness. Reject if dirty.	A	6/30/71	[illegible]
4.4	Anode two flange. Inspect sealing surface for scratches and nicks with a binocular microscope.* Reject if any.	A	6/30/71	[illegible]
4.5	Anode one to Anode two ceramic. Inspect for cleanliness. Reject if dirty or contains markings of any kind.	A	6/30/71	[illegible]
4.6	Anode one contact flange. Inspect for sharp edges or protrusions. Reject if any.	A	6/30/71	[illegible]
4.7	Grid one to anode one ceramic. Inspect for cleanliness. Reject if dirty.	A	6/30/71	[illegible]
4.8	Grid one contact flange. Inspect for presence of serial numbers or any visual dents. Reject if missing or dented.	A	6/30/71	[illegible]
4.9	Filament to cathode annular space. Inspect for cleanliness. Reject if dirty.	A	6/30/71	[illegible]

* 3X magnifier may also be used.

4.10	Filament and cathode contacts. Visually inspect for roundness and concentricity. Reject if obviously out-of-round or dented.	A	6/30/91	[illegible]
4.11	Measure and record dimensions "A" thru "X" per drawing IPC-C-1055-002 sheet number one. Check if out of tolerance and reject.			

DIMENSIONS IN INCHES

	Minimum	Actual	Maximum	✓	A/R	Date	Initial
A	.592	.620	.632	✓	A	7/7	JRW
B	.833	.850	.863	✓	A	7/7	JRW
C	1.105	1.130	1.135	✓	A	7/7	JRW
D	1.425	1.447	1.455	✓	A	7/7	JRW
E	1.784	[illegible]	1.824	✓	A	7/7	JRW
F	.049	.050	.055	✓	A	7/7	JRW
G	.660	.67[illegible]	.690	✓	A	7/7	JRW
H	.110	.12[illegible]	.145	✓	A	7/7	JRW
I	—	[illegible]	1.300	✓	A	7/7	JRW
J	.210	.217	.220	✓	A	7/7	JRW
K	.310	.315	.325	✓	A	7/7	JRW
L	.655	.66[illegible]	.665	✓	A	7/7	JRW
M	1.194	1.201	1.206	✓	A	7/7	JRW
N	1.660	[illegible]	1.668	✓	A	7/7	JRW
O	---	.013	.010 TIR		R	7/7	JRW
P	---	.012	.015 TIR	✓	A	7/7	JRW
Q	---	.020	.025TIR		A	7/7	JRW
R	.250	.274	.325	✓	A	7/7	JRW
S	.045	.077	.125	✓	A	7/7	JRW
T	.120	.124	.130	✓	A	7/7	JRW
U	.031	.050	.124	✓	A	7/7	JRW

					A/R	Date	Initial
V	.062	.077	.125	✓	A	7/7	JRK
W	1.015	1.025	1.035	✓	A	7/7	JRK
X			1.323	✓	A	7/7	JRK

5.0 **Static Electrical Tests**

5.1 Measure cold resistance of the breakseal band with a Hartman and Braun Wheatstone Bridge. Value .195 ohms.

Reject if greater than .5 ohms or less than .1ohms. A 7/26/71 CJ

5.2 Measure cold resistance between cathode and filament with a Hartman and Braun Wheatstone Bridge. Value .60 ohms.

Reject if greater than 1.0 ohm or less than o.1 ohm. A 7/26/71 CJ

5.3 Measure resistance between the cathode and grid one with a Simpson Multimeter Model 260 on the 10,000 ohm scale. *

Value ∞ ohms.

Reject if less than 10 megohms. A 7/26/71 CJ

5.4 Measure resistance between grid one and anode one with a Simpson Multimeter Model 260 on the 10,000 ohm scale. *

Value ∞ ohms.

Reject if less than 10 megohms. A 7/26/71 CJ

5.5 Measure resistance between anode one and anode two with a Simpson Multimeter Model 260 on the 10,000 ohm scale. *

Value ∞ ohms.

Reject if less than 10 megohms. A 7/26/71 CJ

5.6 Measure resistance between anode two and the cap with a Simpson Multimeter Model 260 on the 10,000 ohm scale. *

Value ∞ ohms.

Reject if less than 10 megohms. A 7/26/71 CJ

6.0 <u>Hipot DC Testing</u>

6.1 <u>Test Configurations</u>

The configurations for these tests are shown in figures 6.2 and 6.3.

* RCA model WV98C VTVM on the one megohm scale may also be used.

The unit being tested shall be mounted in test fixture EE65-1, and contained in one atmosphere of dry sulphur hexaflouride gas (SF_6).

6.2 Anode Two to Anode One Hipot Testing

Test configuration in Figure 6.2. Test Procedure:

Hipot in dry SF_6 environment at 1 atmosphere pressure

Increase voltage slowly to 20 kv then proceed in 2 kv steps

Hold voltage for 30 seconds without breakdown at each step from 20 - 28 kv.

At 30 kv hold voltage for 5 minutes. After this period if a gun will not hold 30 kv for at least 30 seconds, it will be rejected.

During 5 minute run record voltage and current every 1 minute and note the number of breakdowns, if any.

During 30 second run record voltage and current at the end of period. Also record the number of breakdowns at each level.

Voltage (KV)	Current(μ amps)	No. of Breakdowns
20	________	________
22	________	________
24	________	________
26	________	________
28	________	________
30	________	________

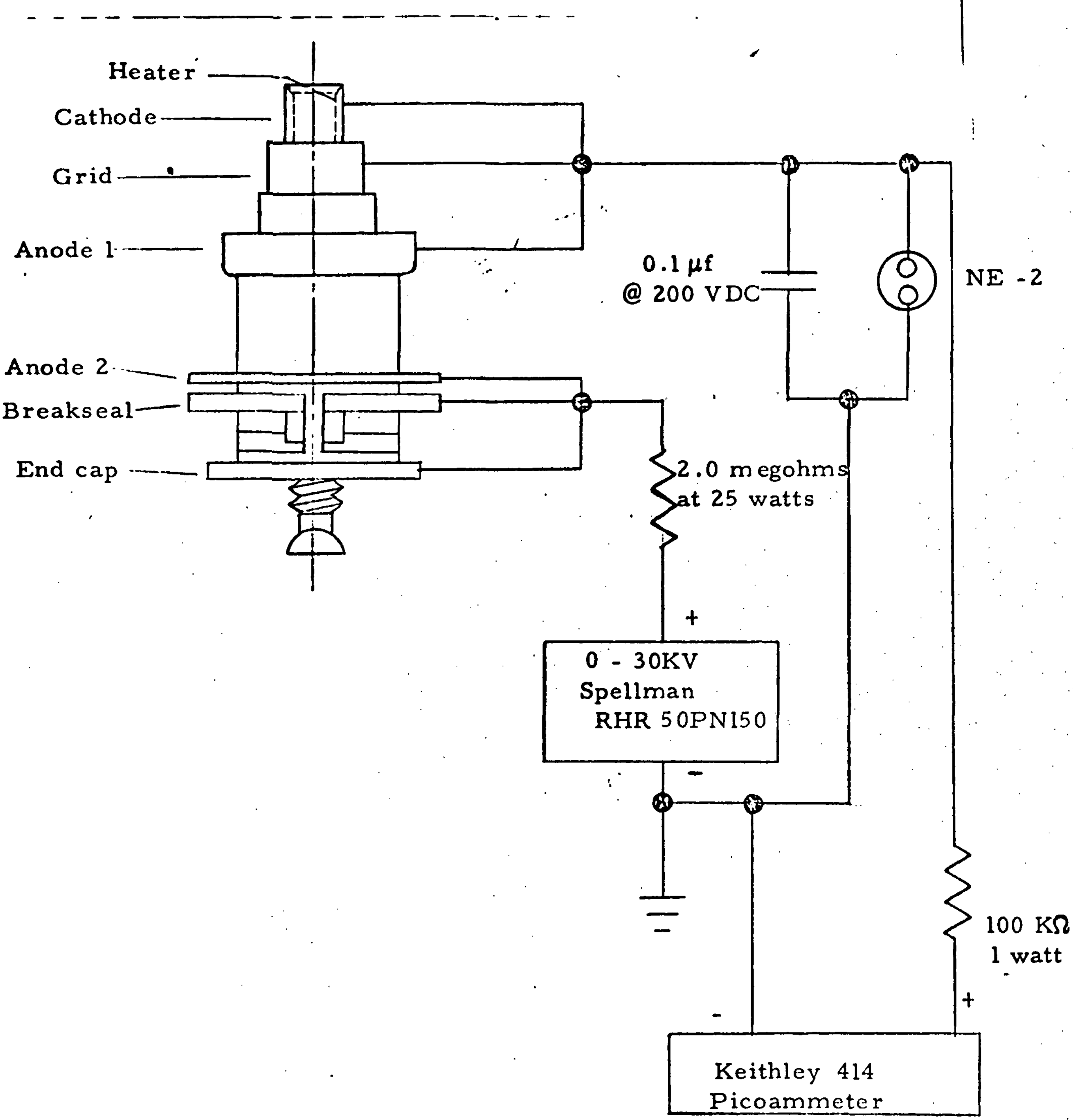
Minute (5 min.run)	Current (μ amps)	No. of Breakdowns
0	________	________
1	________	________
2	________	________
3	________	________
4	________	________
5	________	________

Final 30 second test:

No. of breakdowns ______________

Reject if any

______ A/R   ______ Date   ______ Initial



Anode Two / Anode One Hipot Configuration

FIG. 6.2

6.3 Anode One to Grid One Hipot Testing

Test configuration in Figure 6.3. Test Procedure:

Hipot in dry SF_6 environment at 1 atmosphere pressure.

Increase voltage slowly to 1 kv then proceed in 200v steps

Hold voltage for 30 seconds without breakdown at each step from 1 to 2 kv.

At 2 kv hold voltage for 5 minutes. After this period if a gun will not hold 2 kv for at least 30 seconds, it will be rejected.

During 5 minute run record voltage and current every 1 minute and note the number of breakdowns.

During 30 second run record voltage and current at the end of period. Also record the number of breakdowns at each level.

Voltage (KV)	Current (nA)	No. of Breakdowns
1.0	.1	0
1.2	.05	0
1.4	.1	0
1.6	.1	0
1.8	.1	0
2.0	.12	0

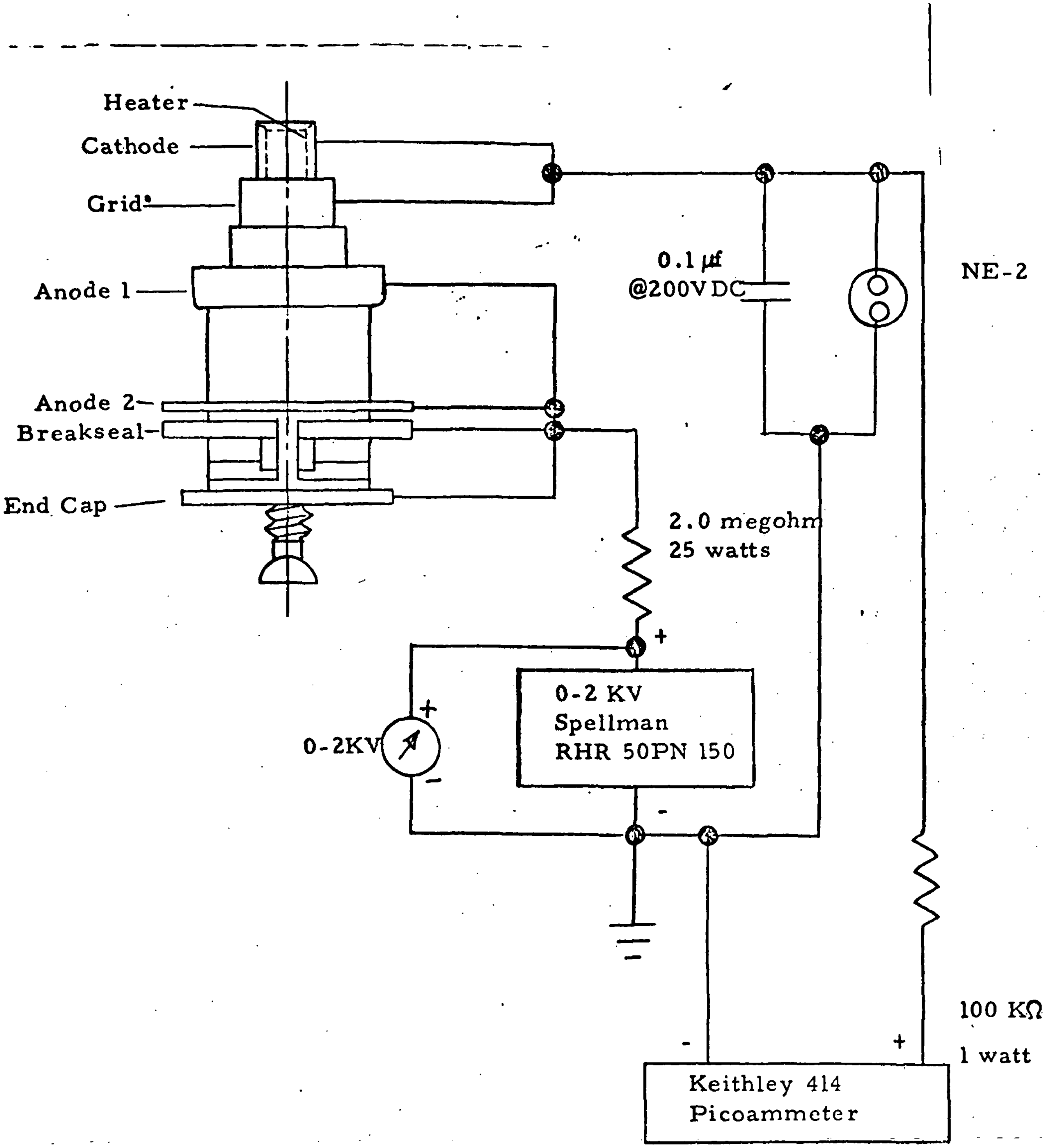
Minute (5 Min. Run)	Current (nA)	No. of Breakdowns
0	.12	0
1	.05	0
2	.05	0
3	.02	0
4	.06	0
5	.06	0

Final 30 second test:

No. of breakdowns Ø

Reject if any A 7/26/71 CJ

A/R Date Initial



Anode One / Grid One Hipot Configuration

FIG. 6.3

7.0 Gun Transfer Characteristic Measurements

7.1 Test Configurations

The configuration for these tests is shown in figure 7.1. The unit being tested shall be mounted in test fixture EE 65-1, and contained in one atmosphere of dry sulphur hexaflouride gas (SF_6).

7.2 Filament Current Tests

Energize filament and determine filament current at 7.5 volts. Accept if current falls between 1.425-1.575 amps. Reject if current is less than 1.40 or more than 1.60 amps. Reject and hold if current is 1.4-1.425 or 1.575-1.6 for review by engineering and Q.C.

Current __________ Amps. ________ A/R ________ date ________ initial

7.3 Grid One Characteristic Measurement

Obtain oscilloscope record of plate-current-grid voltage characteristics for the following conditions with filament at 7.5 volts.

a) Anode two- cathode voltage 5.0KV ± 10%.
Anode one - cathode voltage 250 V ± 5%.

b) Anode two - cathode voltage 10. 0KV ± 10%.
Anode one - cathode voltage 500V ± 5%.

c) Anode two - cathode voltage 20. 0KV ± 10%.
Anode one - cathode voltage 1000V ± 5%.

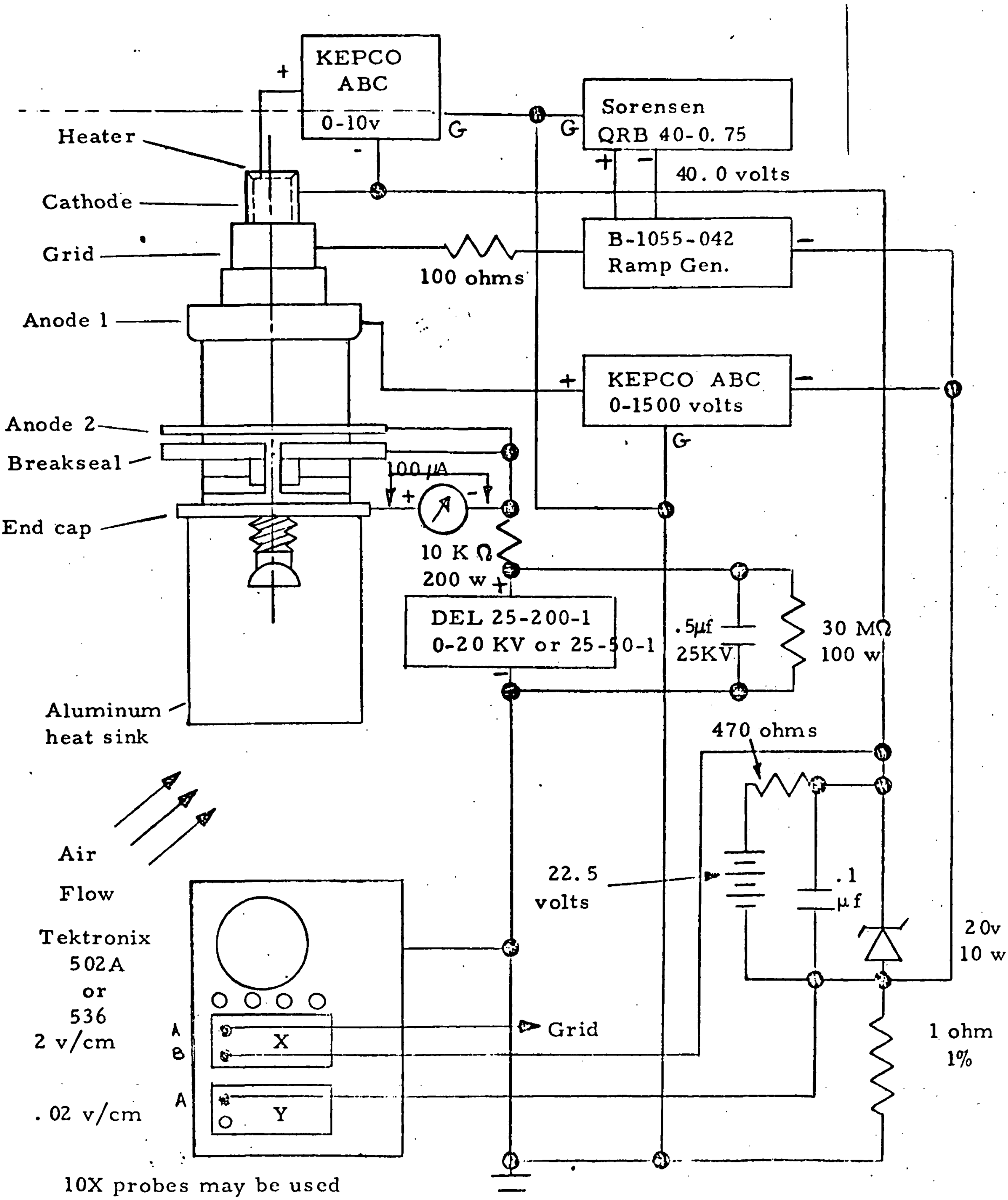
Test performed by manually triggering the 30 volt ramp generator. Do not exceed 10 sweeps on the gun in 1 minute. Be sure that the end cap is properly heat sinked as indicated in figure 7.1.

NOTE: For grid control characteristics to be acceptable at 20KV:

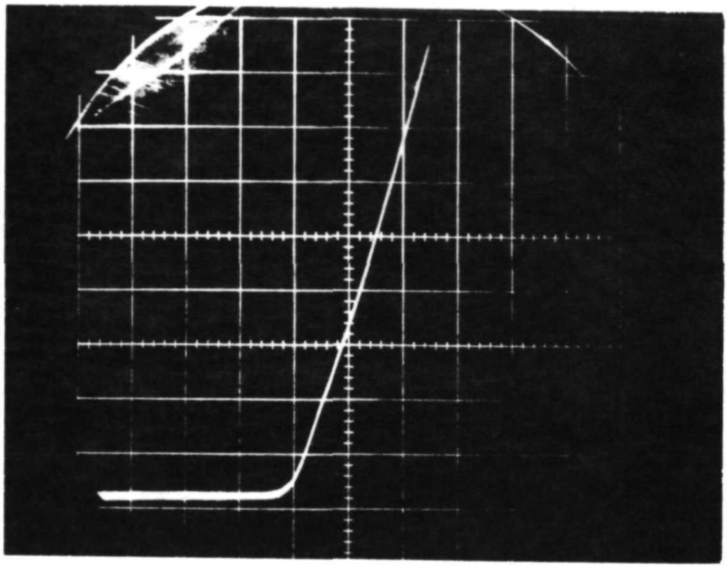
A. The grid bias required to obtain 100 ma return current must fall between -2.5 volts and +.5 volts. ______ Volts @ 100 mA

B. At 100 ma the mutual conductance (g_m) of the tube must fall between 18,200 and 24,600 micromhos. This number is derived by taking from the 20 KV photograph the grid voltage at 80mA (V_{80}) and the grid voltage at 100 mA (V_{100}) and inserting in the following formula:

$$g_m = \frac{20,000}{V_{100} - V_{80}} = \_\_\_\_\_\_ \ \mu\text{mhos}$$

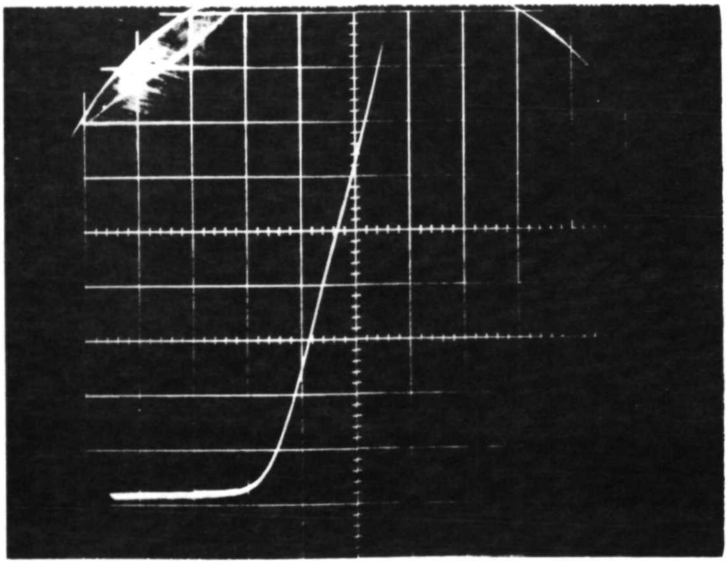


Gun Transfer Charateristic Test Setup
FIG. 7.1



X_____ V/cm

Y_____ mA/cm



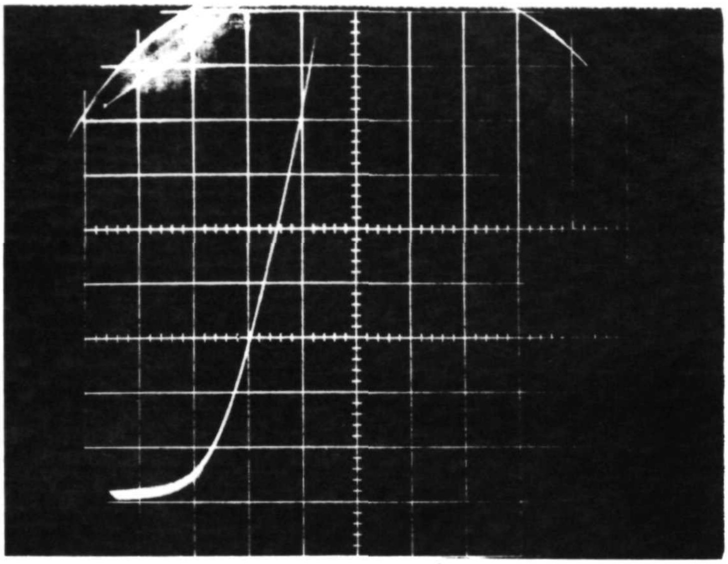
X_____ V/cm

Y_____ mA/cm

10.0KV

X______V/cm

Y______mA/cm



20.0KV

______ A/R ______ date ______ initial

7.4 Grid One Cut-off Test

Test performed by switching B-1055-042 ramp generator to cut-off position. Also remove shorting clip from 100 μ amp meter. Record leakage current under conditions described in section 7.3 (c). Reject if greater than 5 μA.

Current ______________________ μA

______ A/R ______ date ______ initial

Return switch on B-1055-042 ramp generator to ramp position and shorting clip across 100 μamp meter. Initial after completion.

______ date ______ initial

8.0 Final Inspection

8.1 Remove from bench checkout unit and inspect for any changes in appearance - cracks, chips, tracks, evidence of overheating, etc., using a binocular microscope.*

Final Acceptance

Inspector________________________A/R

Quality_________________________A/R

Program________________________A/R

8.2 Replace guns in their original boxes and mark the package accepted, or rejected. If rejected explain reasons in a few words. Inspector should sign and date each box upon completion of the above.

* 3X magnifier may also be used.

TEST SHEET FOR SPECIAL ELECTRON GUN TYPE EE-65-1

DATE 4-12-71

TUBE # 30

TEST	CONDITION	SYMBOL	MIN.	ACTUAL	MAX.	UNIT
Heater Current	E_f = 7.5	I_f	1.25	1.42	1.50	Amps
Insulation of Electrodes	E_f = 0 $E_{b2} = E_k = E_{b1}$ = 0 E_{c1} = -500 V	R	50	[illegible]		Meg
30 kVdc Hipot Test	E_f = 0 $E_{b1} = E_c = E_k$ E_{b2} = 30 kVdc 5 Min. Minimum Hold			OK		
2 kVdc Hipot Test	E_f = 0 $E_{b1} = E_{b2}$ = 2 kVdc $E_c = E_k$ = 0 5 Min. Minimum Hold			OK		
Cut-off Voltage	E_f = 7.5 E_{b2} = 20 kVdc E_{b1} = 800 Vdc I_b = 10 μAdc	$-E_c$	-	6.8	-15	Vdc
Pulse Test	E_f = 7.5 E_{b2} = 20 kVdc E_{b1} = 800 Vdc E_c = -10 Vdc to -30 Vdc e_c/i_b = 100 ma tp = ~~5 ms ± .5 ms~~ [illegible] sec prr = 60 pps	e_c i_c	- -	[illegible] 2.5	10 20	v ma

FIGURE 2

OUTLINE DIMENSIONS FOR EE65-1

(Refer to Figure 7)

Tube Serial Number 30 Date APR 2 1971

Inspector E. Lepine

DIMENSION	MINIMUM	MAXIMUM	MEASUREMENT
A	.592	.632	.611
B	.833	.863	854
C	1.085	1.115	1.125
D	1.425	1.455	1.450
E	1.784	1.824	1814
F	.049	.055	.052
G	.660	.690	.675
H	.110	.145	.120
I	--	1.300	1.245
J	.210	.220	.215
K	.310	.325	.315
L	.655	.665	.660
M	1.194	1.206	1200
N	1.660	1.668	1.662
O	--	.010 TIR	.003
P	--	.015 TIR	.012
Q	--	.025 TIR	[illegible]
R	.250	.325	.300
S	.045	.125	.079
T	.120	.130	.125
U	.050	.124	.079
V	.062	.125	.065
W	1.015	1.035	1.027
X	.168	.192	.176

NOTE: X dimension to be free of solder.

APPENDIX E

VACUUM CHAMBER

APPENDIX E

VACUUM TEST CHAMBER

The main chamber has a 6 foot door on one end, a 32-inch square gate valve at the other and is liberally sprinkled with test and viewing ports. Pumping is achieved with a 50,000 liter/second oil diffusion pump topped with a high thru-put LN_2 cooled optical baffle. A 16 square meter LN_2 cryoliner is available for pumping condensibles or for thermal control. Ultimate vacuum without the cryoliner is 2×10^{-7} torr. With the liner in place, vacuums to 5×10^{-8} torr are possible.

A 4 foot by 4 foot auxiliary chamber which quickly mates to the gate valve is available as needed. This chamber is pumped separately and is also loaded with test and viewing ports. Complete cycling to full vacuum and back to one atmosphere can be accomplished in less than 30 minutes. If this is not fast enough a 400 CFM mechanical pump can pull the chamber to approximately 130,000 foot altitude (1500 μ) in just 60 seconds. Opening the gate valve allows the system to reach 430,000 feet (10^{-5} torr) in another 60 seconds and into the low six range in another minute or so.

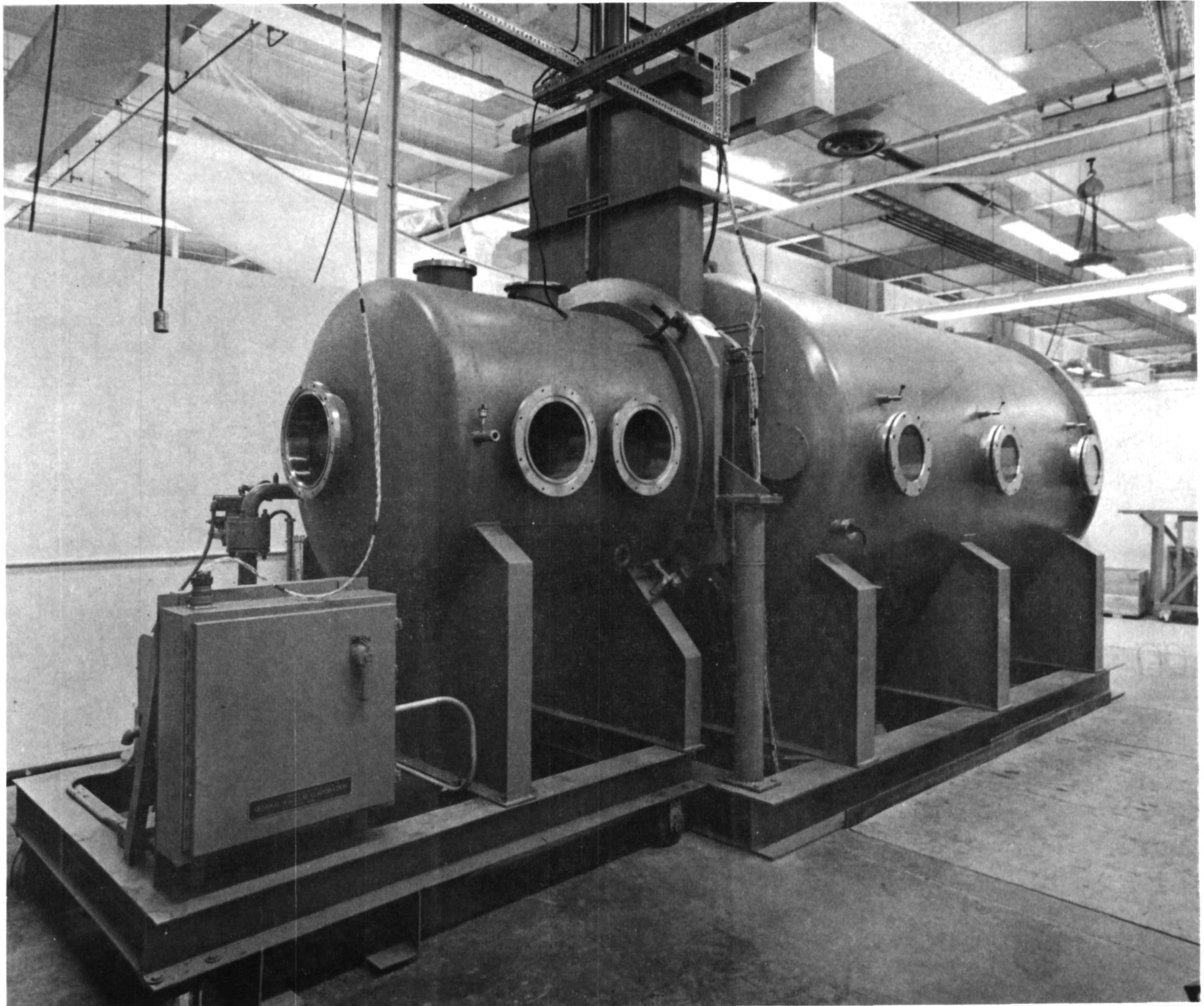


Figure E-1. Vacuum Test Chamber.

ELECTRON GUN TEST REPORT

contract

NAS 9-10399

Prepared for:

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Statement of Work:

The purpose of this investigation was to determine the electron-optical properties of Machlett Laboratories Model EE 65-1 20 KeV electron gun. Also included in the program were tests to prove the design capabilities of the gun, as well as lifetime studies.

Cost and time considerations limited the extent of this investigation to two prototype electron guns.

Experimental Procedure

The experimental program involved three distinct phases:

A. Development and application of an inspection test plan.

B. Shock and vibration proof tests.

C. Open-gun studies.

Initial development of the inspection test plan was begun in August, 1970 before delivery of the prototypes. The plan was designed around an earlier procedure utilized in testing Machlett Labs type EE 65 10 KeV guns used on a previous program. The test procedure included complete mechanical inspection including a dimensional check of all critical parts. Electrical inspection involved tests for dielectric strengths, cutoff, emission, and element to element leakage resistance. All test circuits and equipment for each test was specified in the test plan. The final version of the inspection procedure is contained in appendix A (I/ML-EE65-1 Rev. 3).

Shock and vibration testing was performed according to the schedule shown in Table A. This schedule is the result of the requirements of the STRYPI IV launch vehicle requirement.

TABLE A - SHOCK & VIBRATION TEST SCHEDULE

Sinusiodal Vibration

1g 20 to 500 Hz

6g 500 to 2000 Hz

for 30 seconds all axis

Random Vibration

Frequency 20 to 2000 Hz

PSD Level 0.05 g^2/Hz

Acceleration 10 g rms

Duration 10 seconds each axis

Shock

15 g half sine, 15 milliseconds duration in both directions all axes

The procedure for shock and vibration testing was as follows:

1. Inspect gun to I/ML-EE65-1 test plan.
2. Shock and vibration to schedule in Table A.
3. Reinspect to I/ML-EE65-1.

Only one gun was tested in this manner at one time in anticipation of possible failure. The first prototype was also fully tested in the open-gun mode before the second was put through shock and vibration. Breakseal tabs were tied down according to the flight mounting configuration for purposes of the above test.

Open-gun tests were performed with the test circuit shown in Figure 1 after the breakseals were opened with the circuit indicated in Figure 2. The tests were conducted in a two-foot cube vacuum chamber utilizing a 6" oil diffusion pumping system with freon cooled baffle at -20°F and liquid nitrogen baffle. Base pressure in the aluminum chamber was about 1×10^{-6} torr for all tests. Tests conducted in the open-gun mode were those outlined in Table B.

TABLE B - OPEN GUN TESTS

Test Conditions:

1. E_F = 7.5 volts DC ± 5%.
2. E_{C1} (Bias gl to negative HV) + 40 volts DC ± 5%.
3. E_{C2} variable 250 - 1500 VDC.
4. E_A 5.0, 10.0, and 20.0 KVDC ± 10%.
5. The gun and socket will be contained in one atmosphere of dry SF_6.

of d

6. The first gun tested will be done in a modified EE 65 socket contained in one atm. SF_6. The second gun will be mounted in

socket C-1055-031 in a configuration referenced by C-1055-003 excluding the spinning with the second anode insulated from ground as in the flight pkg.

Tests Performed:

At each anode two voltages of 5, 10 and 20 KV and each cathode current of 40 mA and 90 mA and each anode one voltage of 250, 500, 750, 1000, 1250 and 1500 v.

1. Beam angle via Visicorder
2. Pulse shape for 1 sec and 6 sec via scope photograph
3. Long term test (at least 1 hr) at 20 kv, 100 mA, 50% duty cycle (Vc_2 = 1KV) with 6 second pulses to determine lifetime characteristics.

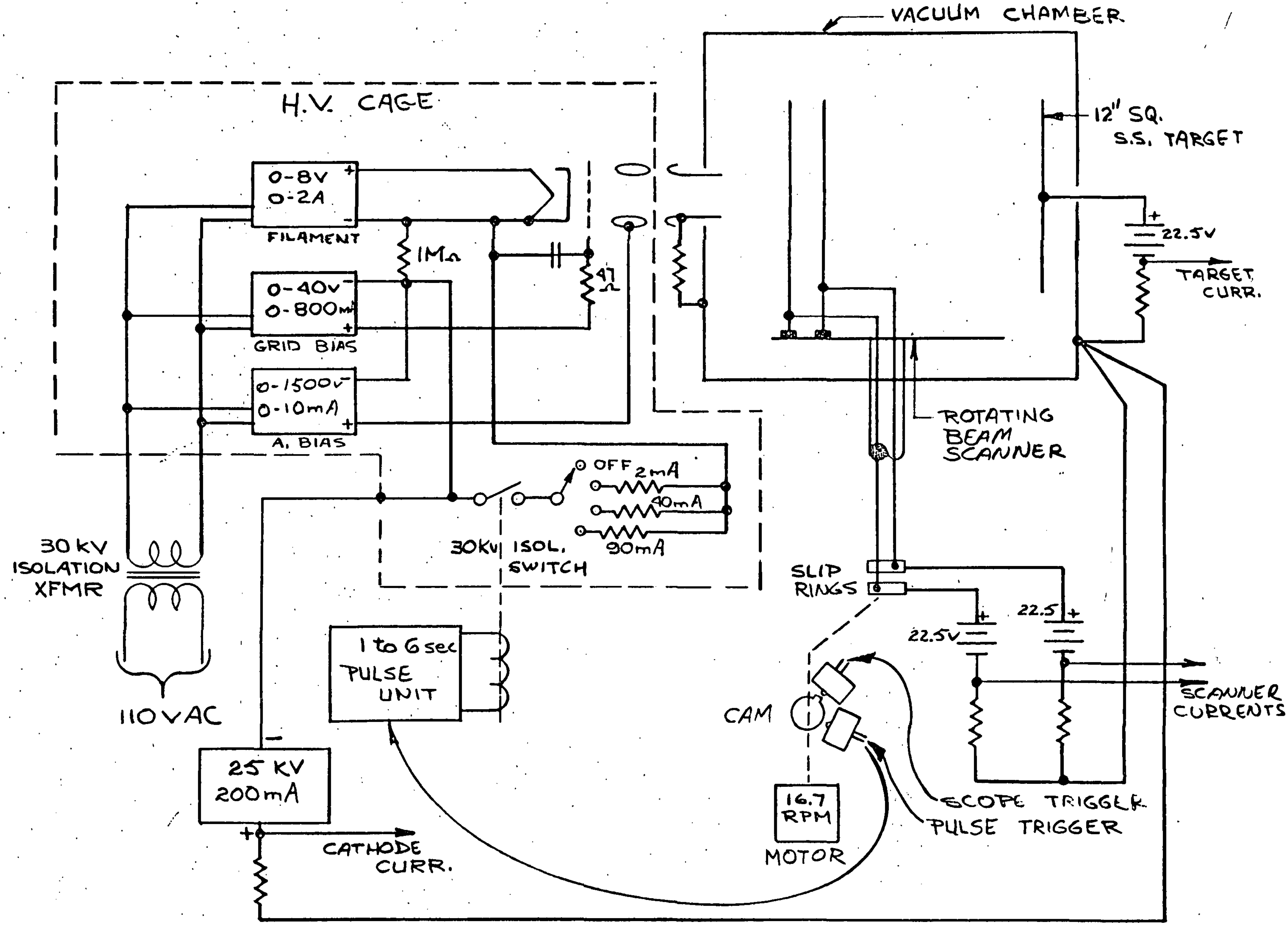


Figure 1 - Optics Test Circuit

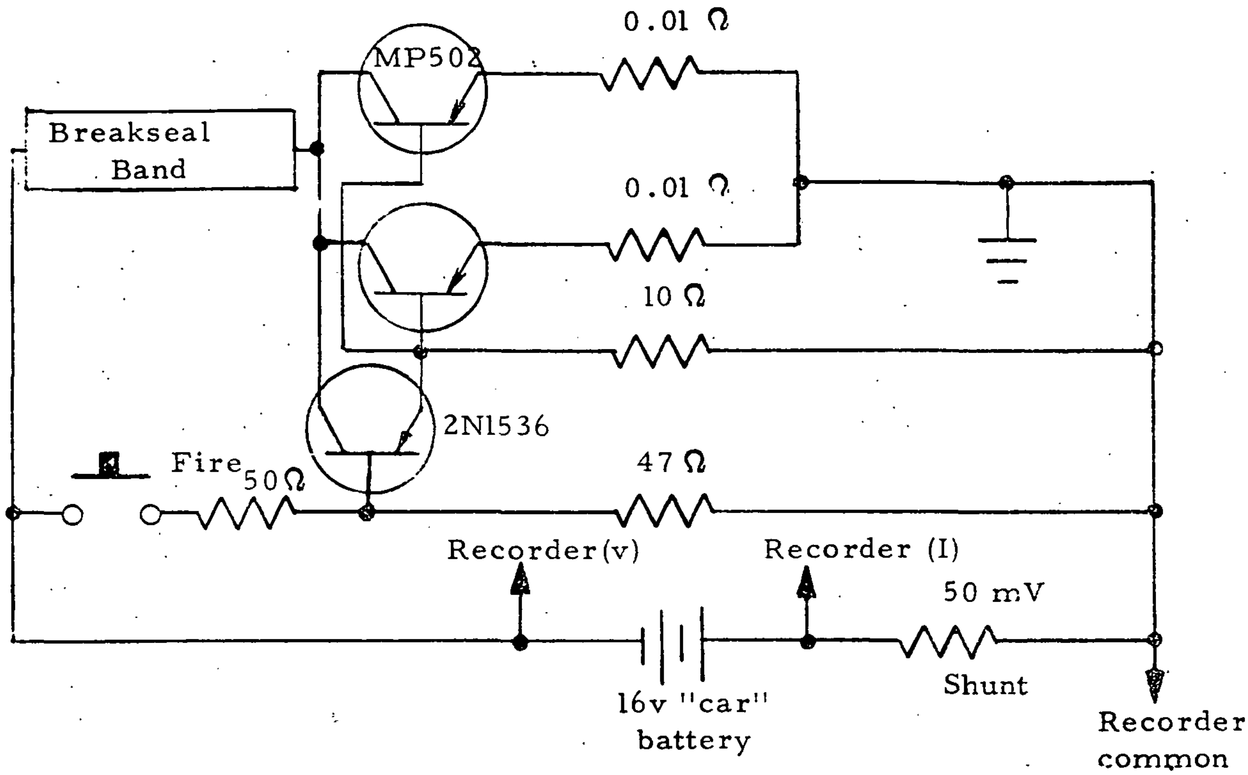


Figure 2 - Breakseal Firing Circuit

Special sensing equipment had to be designed and constructed to determine the shape of the beam and dissipate the 2000 joule pulse emerging from the gun. A beam scanning system was constructed. This consisted of a 16.67 RPM synchronous motor driving a 1/2 inch diameter Wilson rotary seal. On the inside of the vacuum chamber were mounted two 1/8" diameter tungsten rods on a 12" diameter disk tied to the rotary seal. The rods were located 2 inches and 6 inches from the axis of rotation. (see Fig. 3)

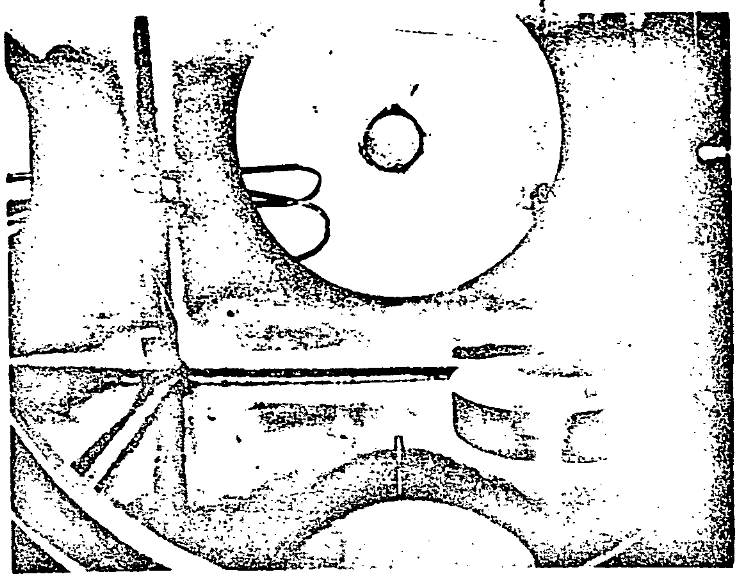


Figure 3 - Beam Scanner

This system allows position sampling of the beam in the vertical plane at distances of 6, 10, 14 and 18 inches from the gun mounting flange. Assuming axial symmetry, the beam shape and size can be determined from this system. Any significant radial accelerations from space charge can also be detected.

Angles of beam divergence are calculated from the readouts by the following method. Given that the scanner is rotating at 16.67 RPM, the velocity of the scanner probe at a radius of 6 inches is:

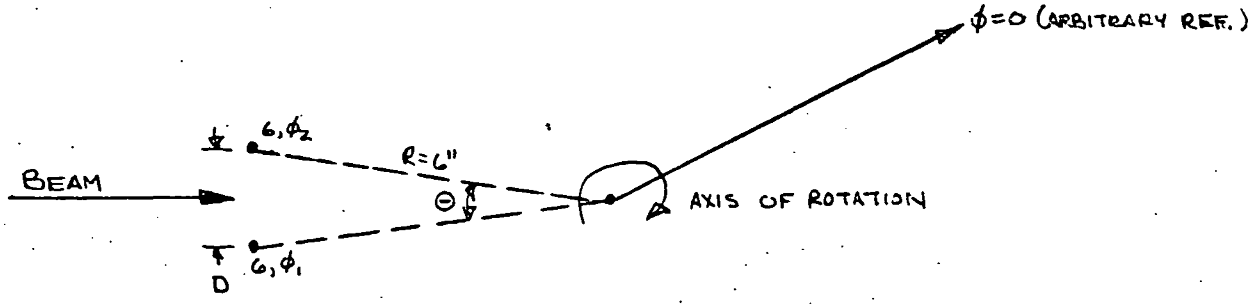
$$V_6 = 16.67 \text{ RPM} \times 1/60 \times 2\pi \times 6 = 3.33\pi \cong 10.5 \text{ in/sec}$$

which is also 100° /sec

For small angles, ($< 10^{\circ}$) the size of the beam is simply:

D = 10.5t, where t is the measured quantity (on chart recorder) assuming the beam lies on a line between the center of the gun and the axis of scanner rotation. For larger angles, i. e. >10 , corrections must be made for the circular travel of the scanning probe.

Looking at Figure 4,



$$\phi = 100t > 0 \leq t \leq 3.6$$

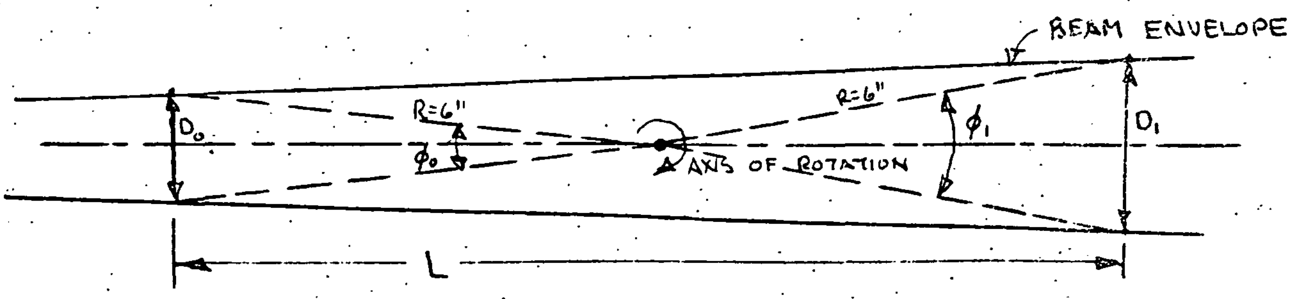
$$D = 2.6 \sin \frac{(\phi_2 - \phi_1)}{2} = 12 \sin \theta/2 = 12 \sin (50t_2 - t_1)$$

let $t_0 = t_2 - t_1$

$$D = 12 \sin 50\, t_0$$

Again, assuming the beam lies on the line through the axis of rotation, and that it is expanding uniformly (no space charge) we can take the measurements at two points and determine the exact angle of divergence.

Going to Figure 5.



ψ (angle of beam divergence) is :

$$\psi = \frac{57.3}{L} [D_1 - D_0]$$

now $D_0 = 12 \sin 50 t_0$

$D_1 = 12 \sin 50t_1$

$$L = 6 \cos 50\, t_0 + 6 \cos 50 t_1$$

then

$$\psi = 57.3 \; \frac{2 \sin 50 t_1 - 2 \sin 50\, t_0}{\cos 50\, t_0 + \cos 50 t_1}$$

$$\psi = 114.6 \; \frac{\sin 50 t_1 \; - 2 \sin 50\, t_0}{\cos 50 t_0 + \cos 50 t_1}$$

$$\psi = 114.6 \tan 1/2 \, [\, 50 t_1 - 50 t_2]$$

$$\psi = 114.6 \tan \, [\, 25 t_1 - 25\, t_2]$$

If we assume a uniform divergence of the beam,

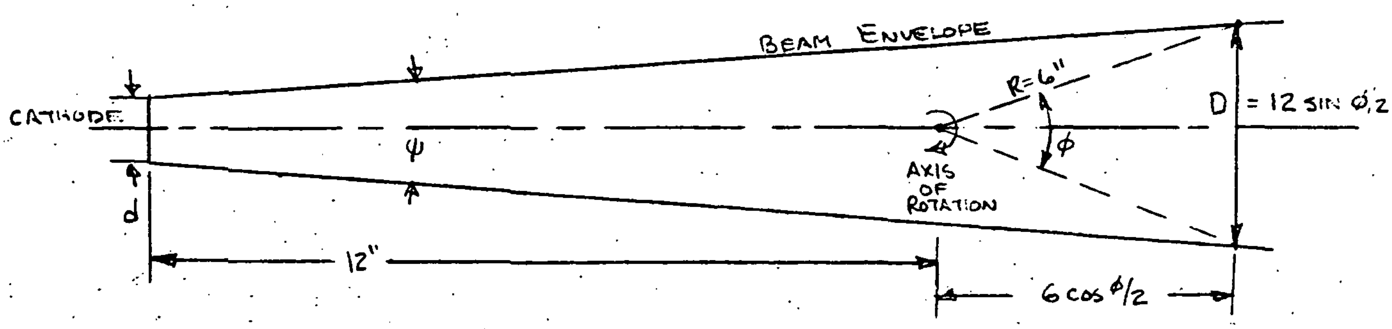


Figure 6

$$\psi = 57.3 \; \frac{D - d}{12 + 6 \cos \phi/2} \; = \; 57.3 \; \frac{12 \text{ in } \phi/2 - d}{12 + 6 \cos \phi/2}$$

again $\phi = 100\ t$

$$\psi = 57.3 \; \frac{12 \sin 50t \; - d}{12 + 6 \cos 50t}$$

or $$\psi = 9.55 \; \frac{12 \sin 50t - d}{2 + \cos 50t}$$

A simple solution would be

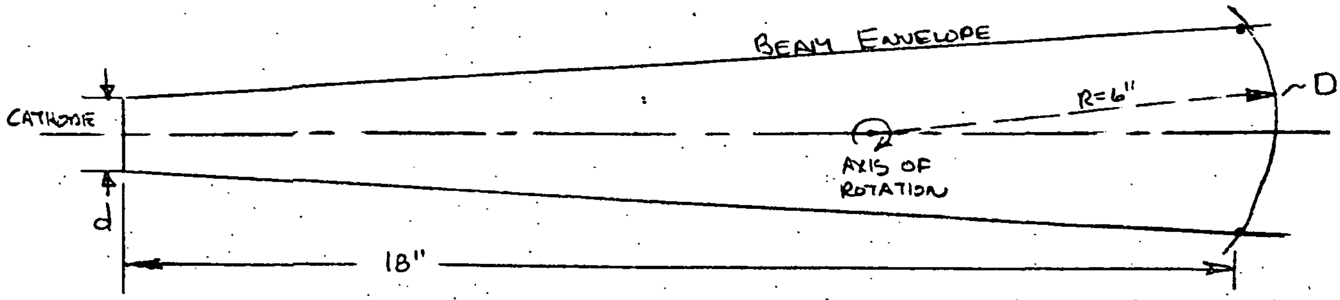


Figure 7

$$\psi = 57.3 \frac{D - d}{18} = 57.3 \frac{10.5t - .4}{18} = 57.3\,(.584t - .022) = 33.4t - 1.27$$

It can be shown that the simple solution is adequate in this case up to $\psi = 15$ with less than 10% error.

For situations where the axis of the beam is located significantly away from the center of scanner rotation, complex corrections are required. See Figure 8.

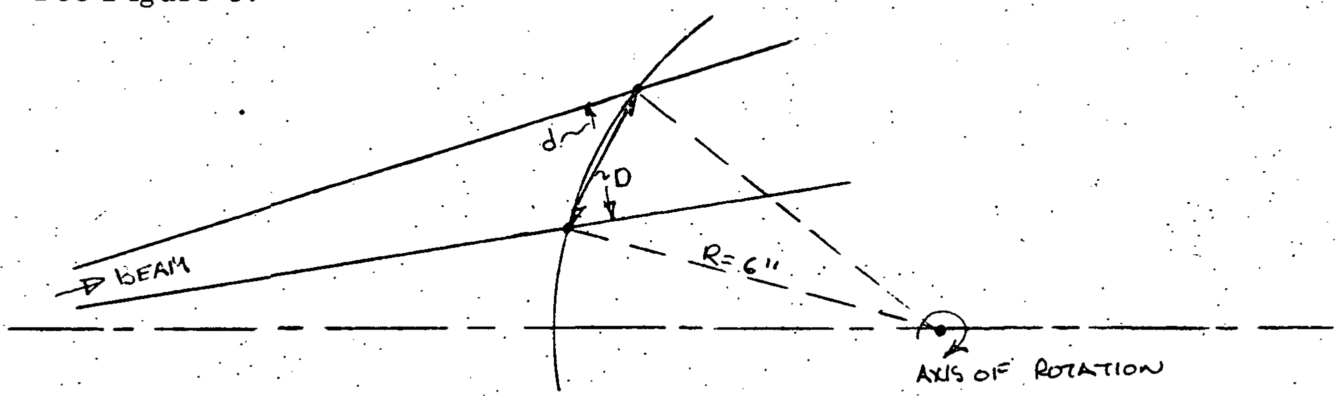


Figure 8

As can be seen, the scanner will give a size, D which is greater than the desired number d. Corrections of this nature were not expected to be required and indeed did not occur in the experimental data.

The beam target consisted of a 12" square stainless steel plate with water cooling. The plate was biased at + 22.5 volts for purposes of secondary-electron suppression so the target could be utilized to measure pulse shape and amplitude for beams of less than 28° full cone angle. Of specific interest was the shape of the leading edge of the pulse where certain discontinuities were found to occur with the older EE 65 gun.

Results

Before presenting the results of this investigation, it is useful to list the specifications of the electron gun as supplied by the manufacturer.

Specifications - EE 65-1

Breakseal

V	15 ± 1 V RMS
I	60 Amps Max inrush
t	3 ± 1/2 sec to break in air

General

Filament voltage	7.5v RMS
Filament current	1.5A RMS
Grid #1 bias for cutoff	-15 VDC max
Anode #1 bias	+ 800 VDC nominal
Anode #2 bias	+ 20,000 VDC
Beam current	100 mA min.
Beam size	10° half-cone max
Lifetime	10 min @ 33% duty cycle in open mode

Table C

Preliminary inspection:

During the first phase of experimentation, some basic problems were discovered with the inspection test plan. The initial form of the plan called for the inspector to perform certain grid characteristic tests by manually sweeping the grid one bias. This particular method would allow large amounts of energy input to the end cap of the sealed gun.

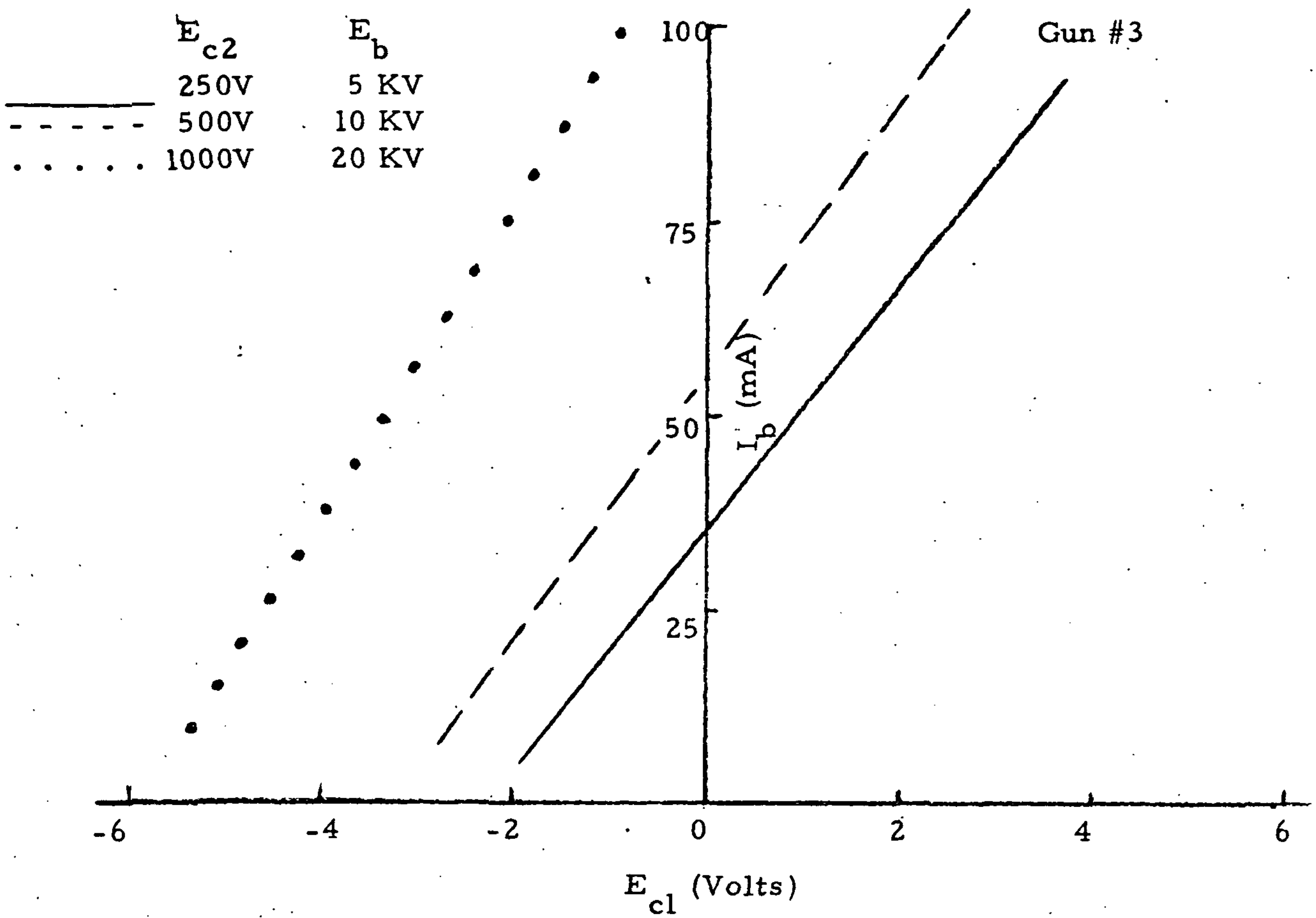
Even though the gun cap was properly heat-sinked for large energy pulses, the vacuum pinch-off was not. This problem resulted in a vacuum failure of the serial #1 gun during first inspection at IPC. A complete failure analysis report is contained in Appendix B. This failure brought about a change in the inspection plan to incorporate automatic grid bias sweeping of a maximum duration of 10 msec with fail-safe protection occurring at 15 msec. A schematic of the special sweep circuit is shown in Appendix C. This system allows only about 10 joules per sweep being applied to the endcap vs over 1000 joules in the earlier version of the test.

After the failure of the first gun, another prototype was obtained, so we still had two acceptable units for analysis. Pre-vibration inspection was then completed with the results tabulated in Table D.

Table D

Summary of Inspection Data

Gun	Mechanical & Dimensional Check	Filament I @ 7.5 VRMS	Transconductance μ mhos
3	OK	1.55 A	20,000
4	OK	1.50 A	22,500
	Grid Bias ($E_b = 20KV, E_{c2} = I_k = 100mA$)	Leakage $I_F = 0, E_b = 30KV, E_{c1} = E_{c2} = 0$	
3	-0.8v	200 μA	
4	-1.8v	300 μA	



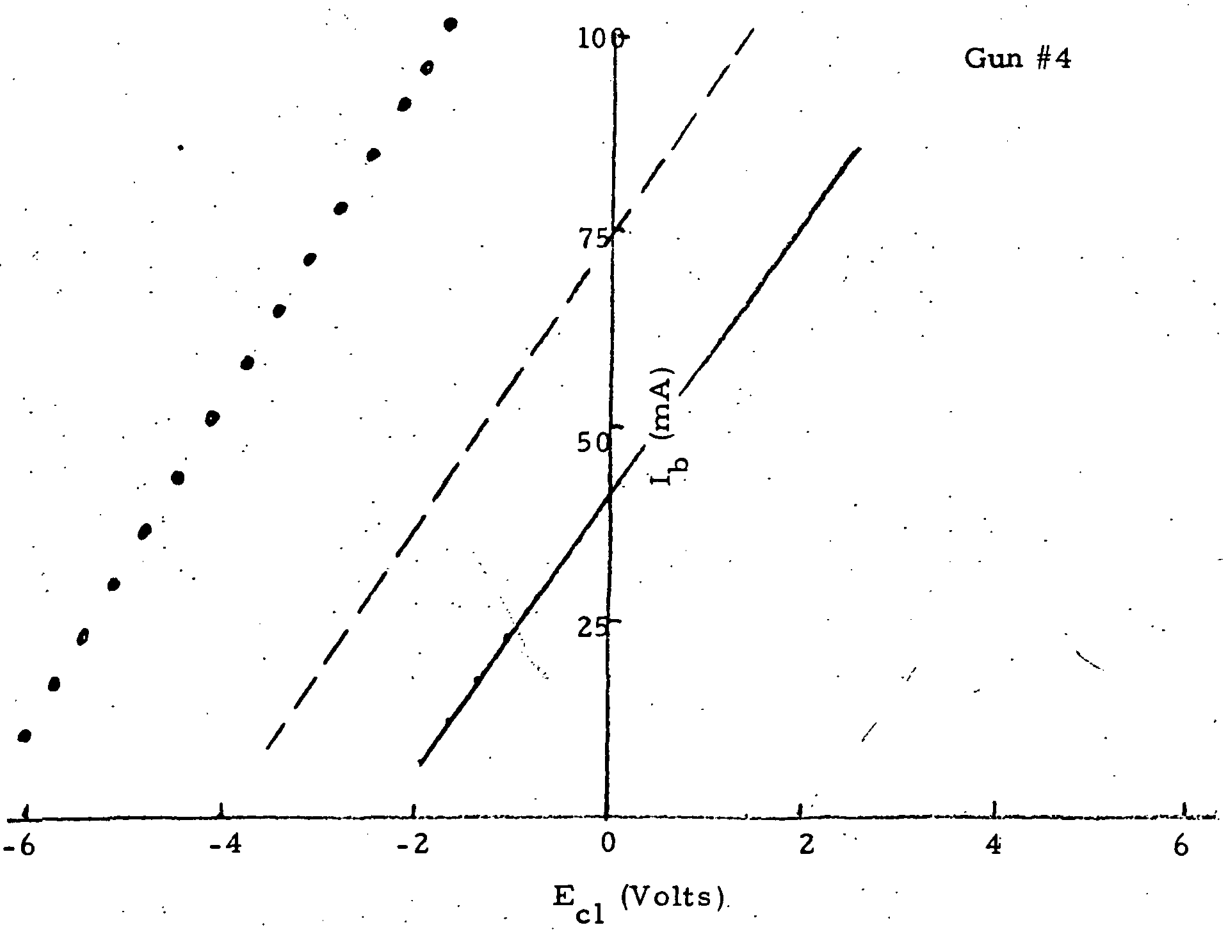


Table D con't. Gun Transfer Characteristics

Shock and Vibration

The shock and vibration tests scheduled in Table A were performed at Associated Testing Laboratories in Burlington, Mass. on Sept. 16 and Oct. 13 respectively for gun serial numbers 3 and 4. Serial #3 was tested first and then returned to IPC for reinspection and open-mode analysis. This procedure was intended to insure viability of the first prototype before vibration testing of the second, in case difficulties caused by such testing were not detected by normal inspection procedures.

The test reports from shock and vibration analysis are found in Appendix D in total. Post shock and vibration inspection at IPC was completed without difficulty and no significant deviations from the results in Table D were noted in either prototype gun.

Breakseal Testing:

Because the breakseal system was by design, the same as that used on the EE 65 gun, it was determined that only simple proof testing of a number of breakseals would be required. Considerable effort by the quality assurance section insured that not only the design was exactly as before, but that the materials and production processes were identical. Therefore only three breakseals have been activated at IPC (the 2 prototypes plus serial #1 gun), and three at Machlett Labs under the auspices of the government source inspector.

The simple testing at IPC involved firing the breakseal at 15 ± 1 volt to show that it did work and that the time to break would be less than 3.5 seconds (the specified upper limit). The tests at Machlett were to the specification of 3 ± 0.5 seconds.

The current and voltage recordings of the three breakseals opened at IPC are shown in Figures 9a, b, & c with the time scale as indicated.

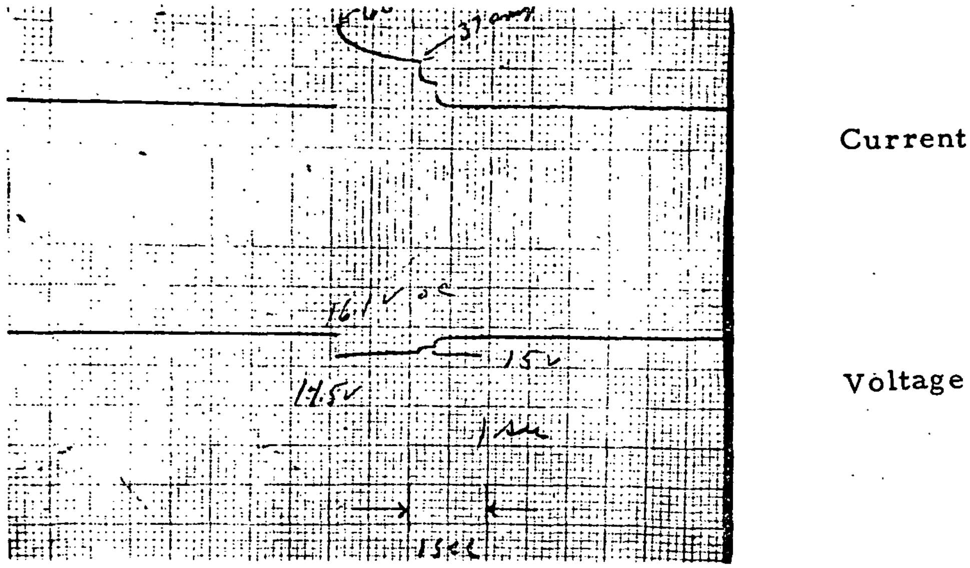


Figure 9a - Gun #1 Breakseal

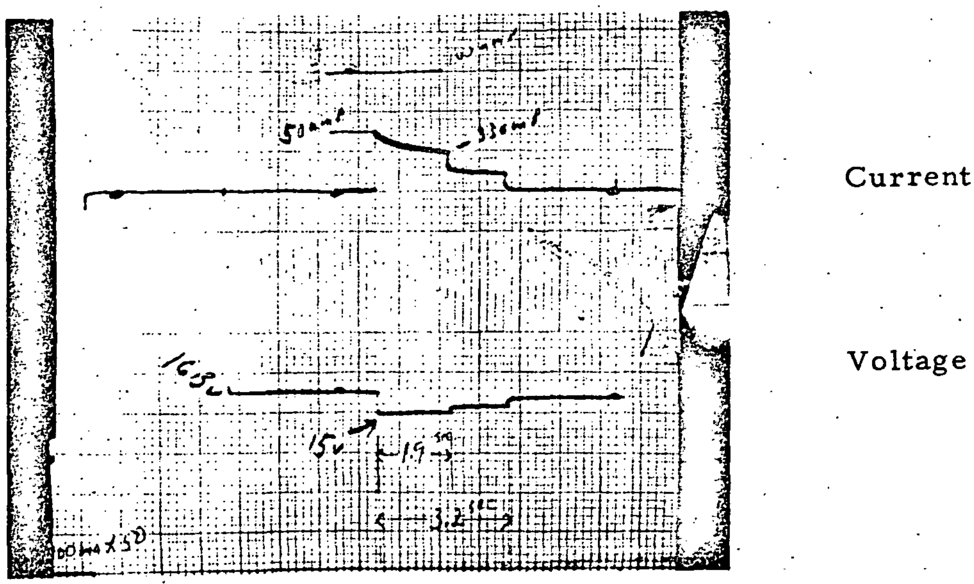


Figure 9b - Gun #3 Breakseal

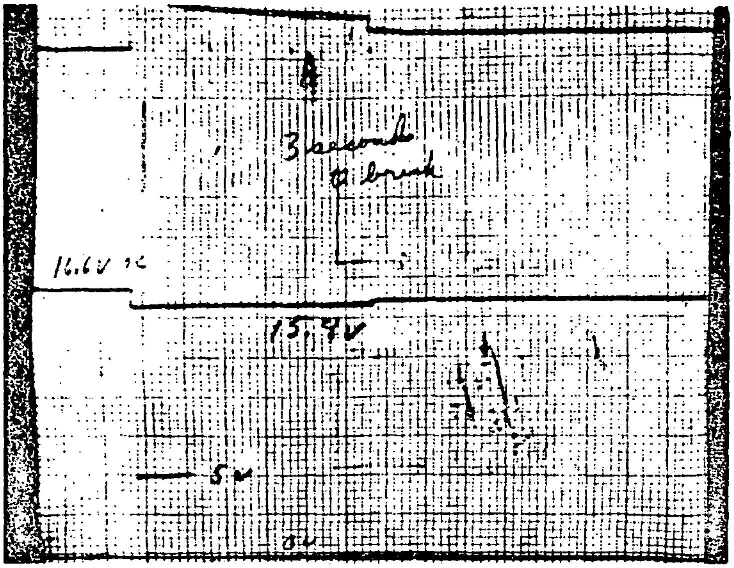


Figure 9(c) Gun #4 Breakseal

Three breakseals were opened in air on 12/16/70 at Machlett Laboratories as proof of performance. All three opened within 3 ± 0.5 seconds with 15 v RMS 60 Hz AC applied.

The first two breakseals were opened with a simplified version of the circuit in Figure 2, as shown in Fig. 10. The last gun (serial #4) was opened with the full circuit of Figure 2 as this represented the system to be used on the flight payload, with the exception of the use of lead-acid "car" batteries in place of the not-yet-available silver-zinc flight cells.

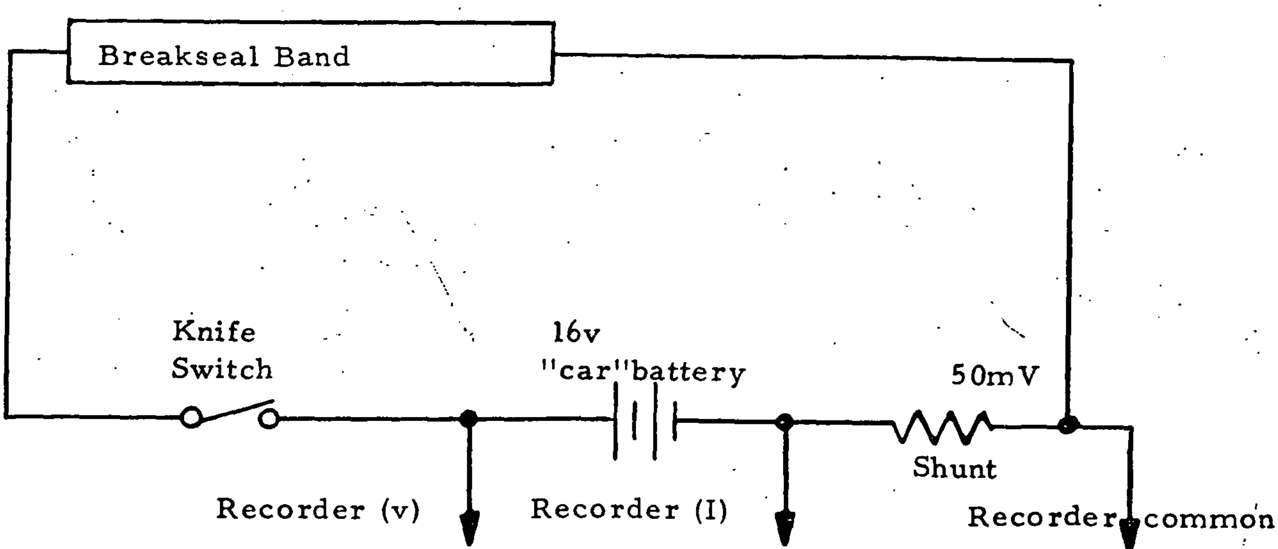


Figure 10 - Simple Breakseal Firing Circuit

Electron Optical Studies:

The tests outlined in Table B were utilized during these experiments and the data compiled in a series of graphs and photographs. The first gun to be tested (in the circuit of Fig. 1) was found to have no emission when first turned on. This was traced to a leak of sulfur hexaflouride gas being used around the gun for insulation, resulting in a poisoning of the cathode. The cathode was reactivated per Machlett Labs' procedure as outlined in Table E.

Table E - Reactivation Procedure for Cathode

I_f = 1.4 amps

I_{c1}(mA)	I_{c2}(mA)	E_{c2}(mA)	Ib(mA)	Eb(volts)	Time(min)
30					5
50					5
100					3
40	40	225			5
30	10	250	35	400	5
30	11	325	50	800	10
30	11	350	60	1000	10

The first gun was mounted in a modified EE 65 socket, as the new sockets were not yet available. The second gun (serial 4) however, was mounted in a fixture with demensions identical to the intended flight package to test voltage holding ability. The socket used in the second case is a special design resulting from a cooperation between IPC and Jettron Products, Inc. of Hanover, New Jersey. A picture of the socket, test plate, and gun is shown in Figure 11.

Also included was an insulating coating underneath the gun mounting flange (Martin hardcoat anodizing) as was intended on the flight package for purposes of monitoring the second anode current. The results of this test were inconclusive as short occurred between anode 2 and ground after a few pulses. The short's origin was not traced as after the test plate was removed from the vacuum system, no evidence of a short remained.

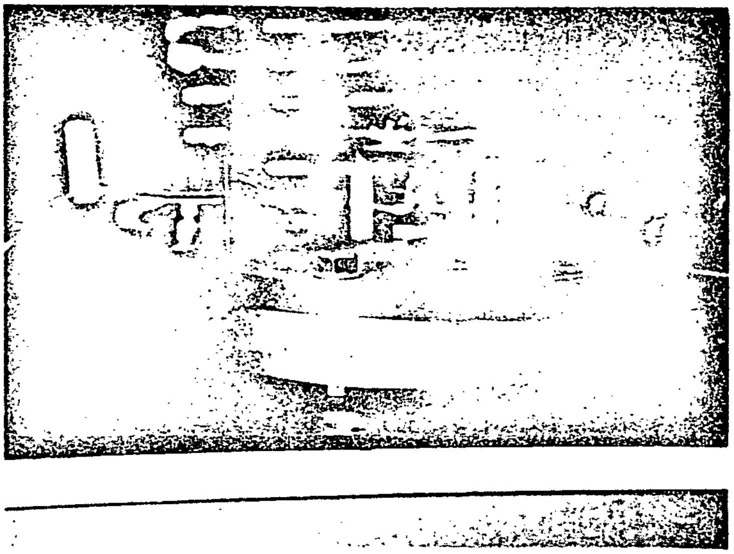


Figure 11 - Gun Test Fixture

A typical data readout from the Visicorder is shown in Figure 12 with the various signals identified. Certain types of data could not be handled by the Visicorder because of their origin being at the cathode potential (in this case the anode is at ground, the cathode at -20Kv) and had to be recorded by hand. Pulse shape data taken from the beam target was done with a Tektronix storage CRT and Photographed.

Reduction of the data taken as shown in Figure 12 was accomplished by measuring the FULL WIDTH AT HALF MAXIMUM (FWHM) in time on the 18" probe and reducing this to a number corresponding to the angle at half maximum by the techniques outlined earlier. The total data was first analyzed to see if indeed the beam did pass through the axis of scanner rotation and that space charge effects were negiligible (i.e. no radial acceleration). As these conditions were found to be true, a simple reduction was allowable. Analysis of the scanner traces also indicated that the base widths of the scanner data were about 2 x FWHM in time. Individual gun results as a function of output current and energy plotted against the first anode bias shown in figures 13 and 14 with composite data displayed in Figure 15.

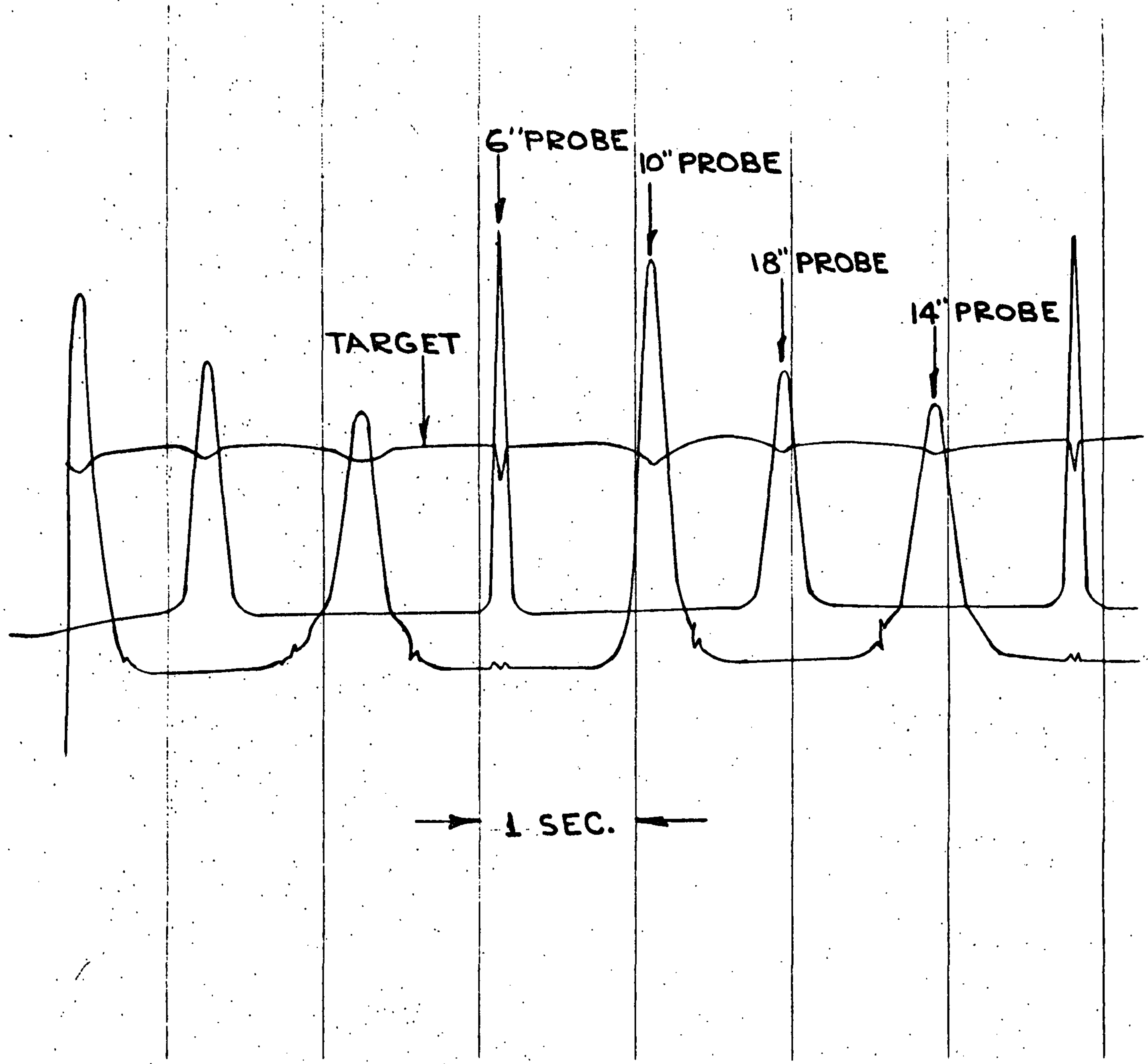


FIGURE 12- TYPICAL BEAM SCANNER DATA

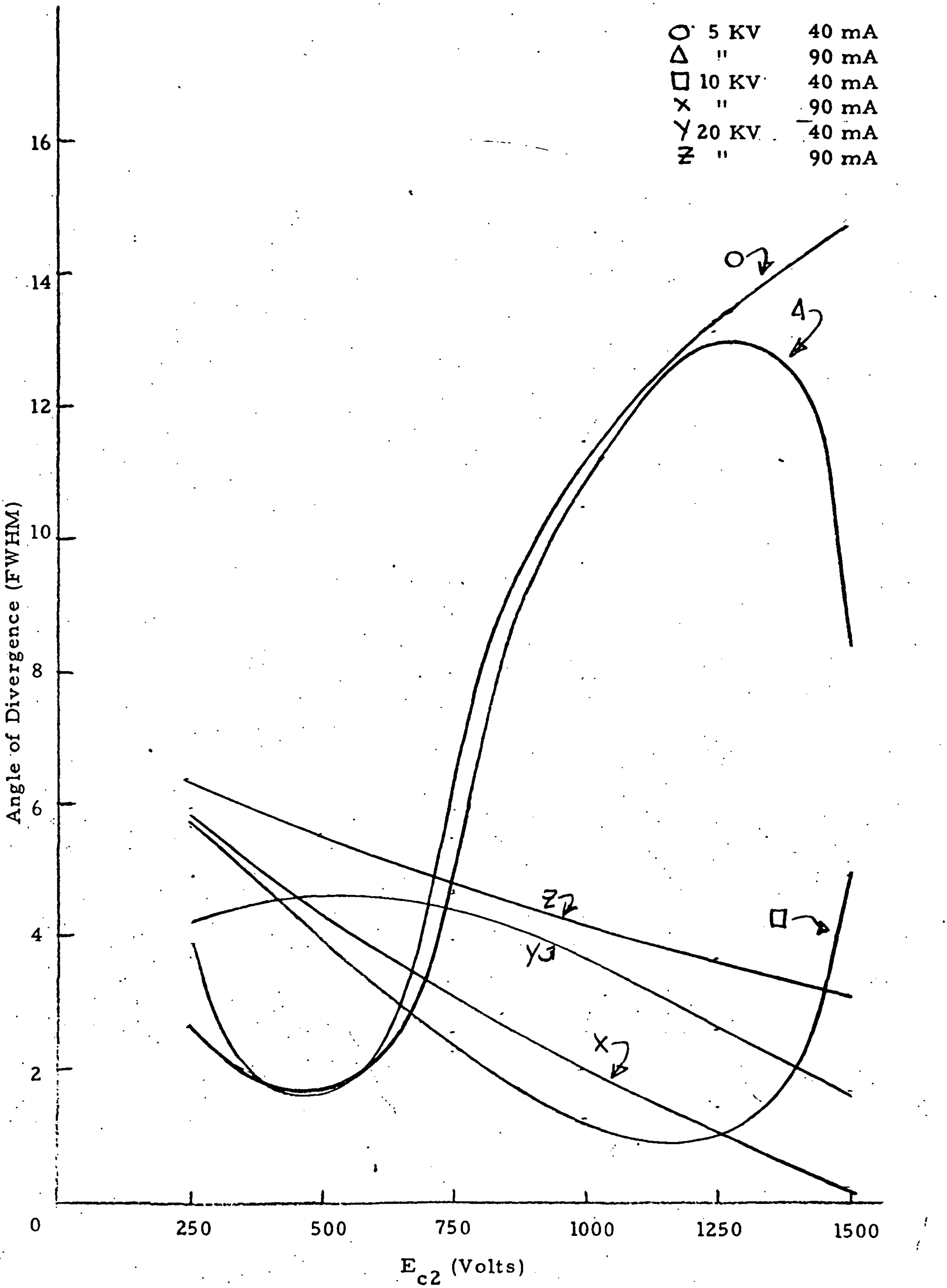


Figure 13 - Gun #3 Optics

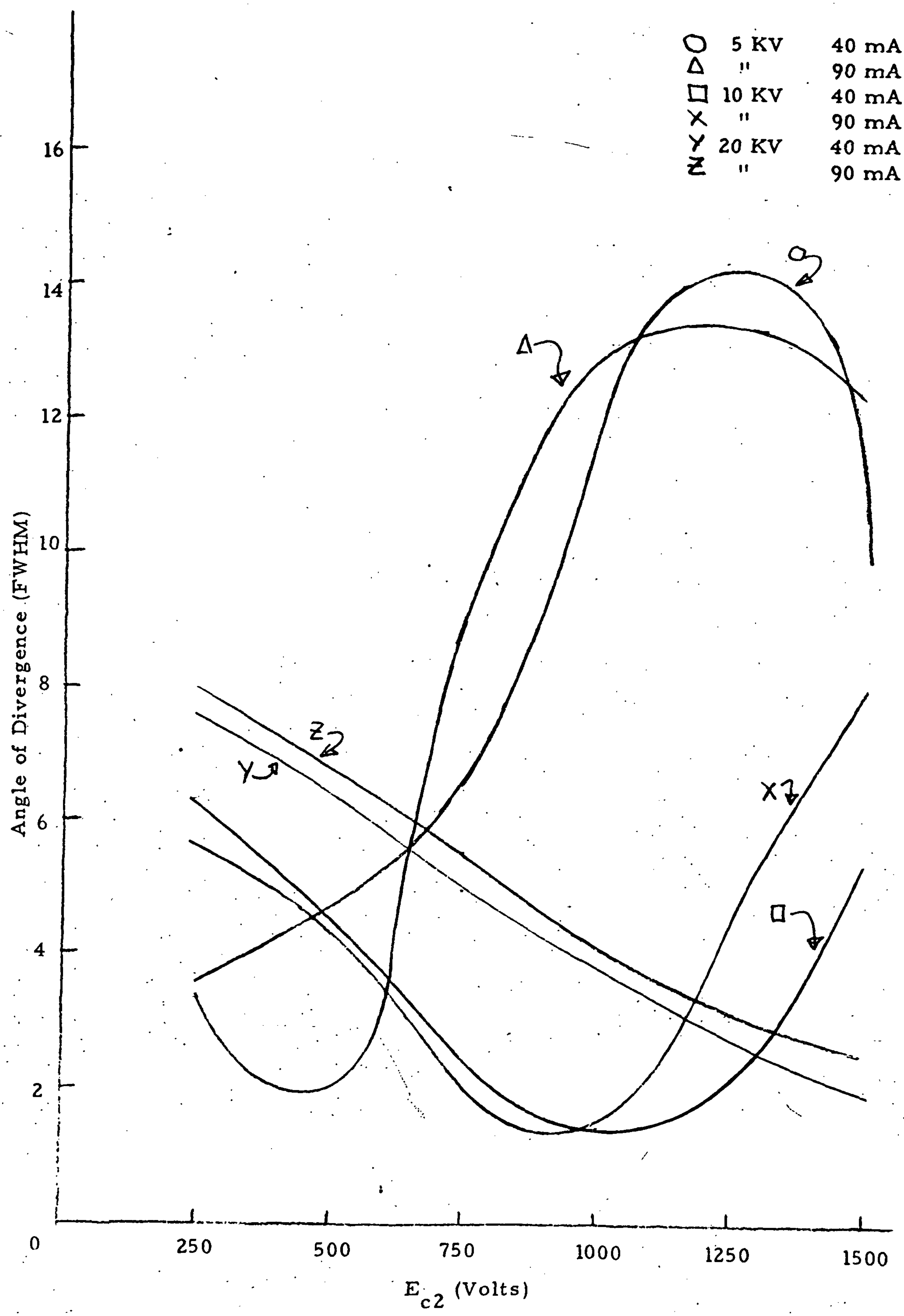


Figure 14 - Gun #4 Optics

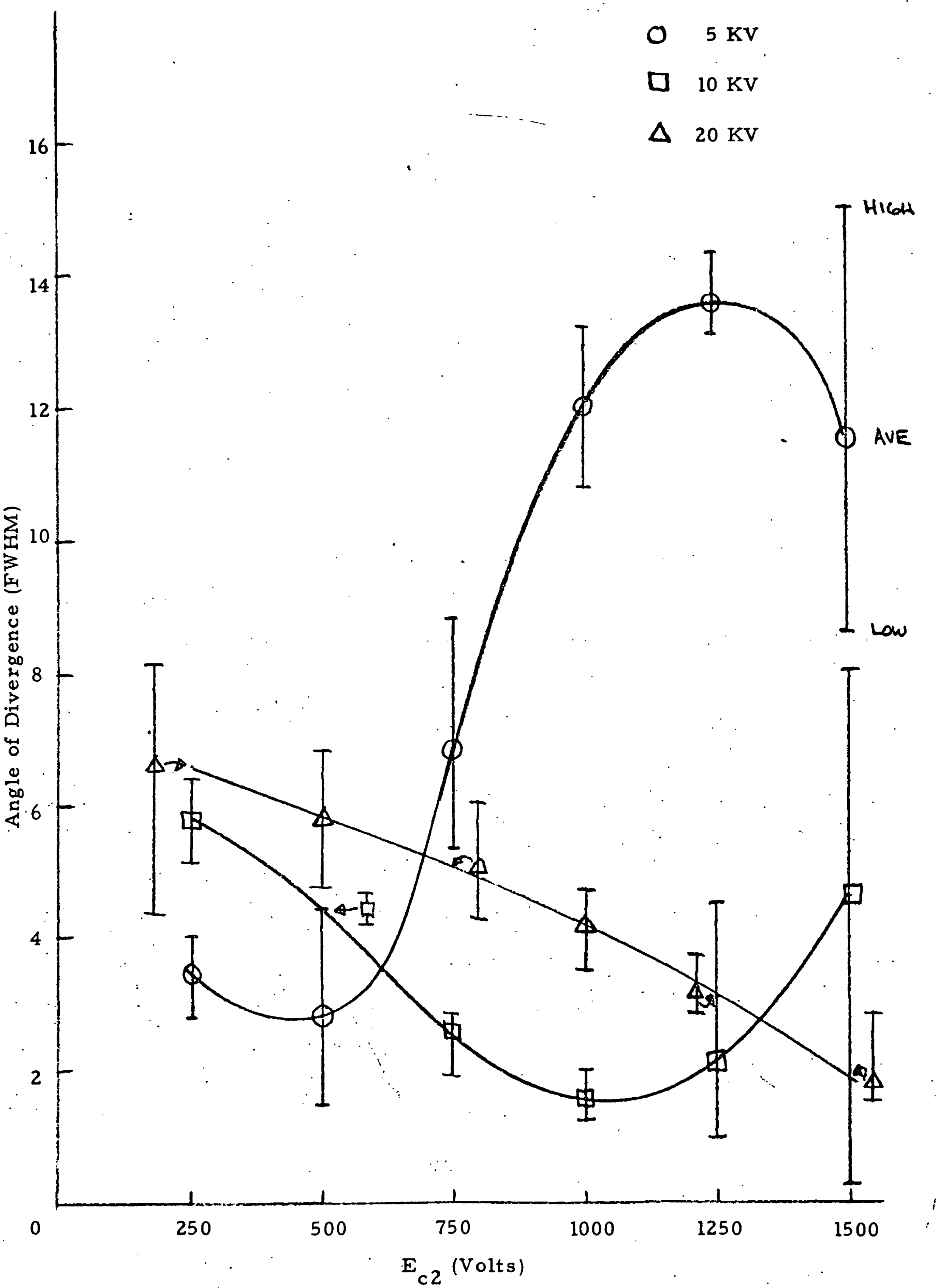
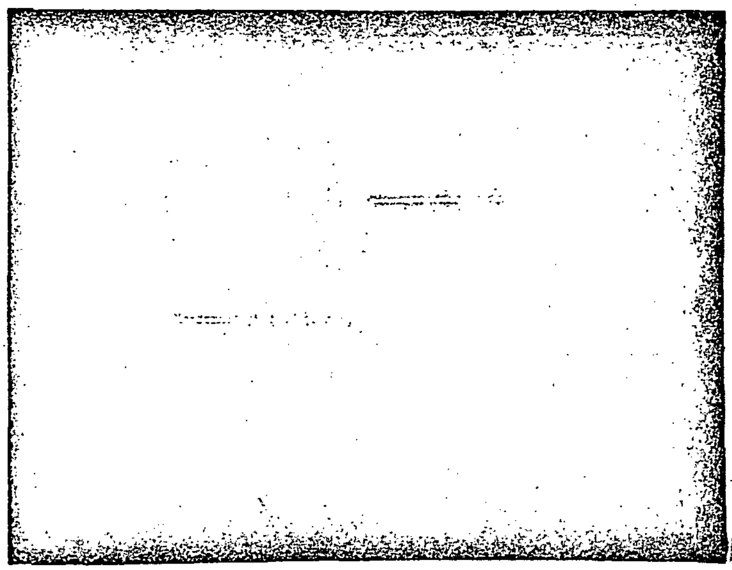


Figure 15 - Average Optics

Data was taken at cathode currents of 40 and 90 mA as these were points corresponding to slightly greater than the intended flight operating currents of 33 and 83 mA.

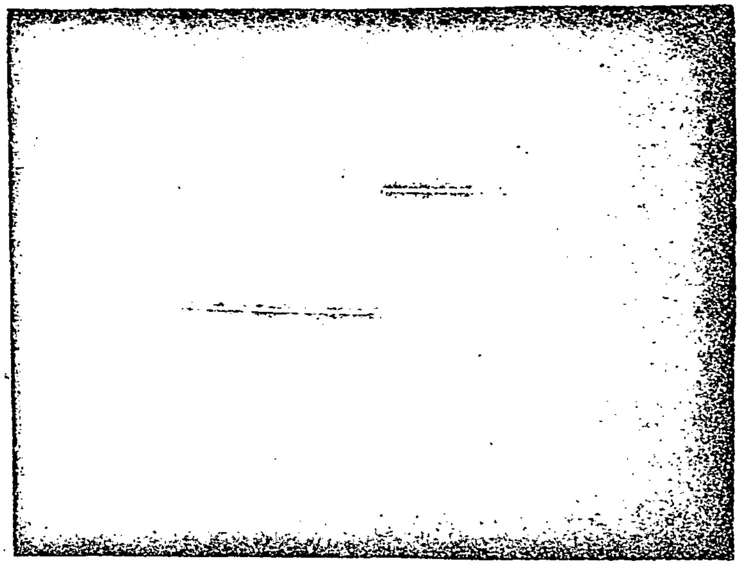
Pulse shape data taken with oscilloscope photographs is shown for representative 1 and 6 second pulse lengths in Figures 16 through 21.



→ .2 sec/cm

↓ 20 mA/cm

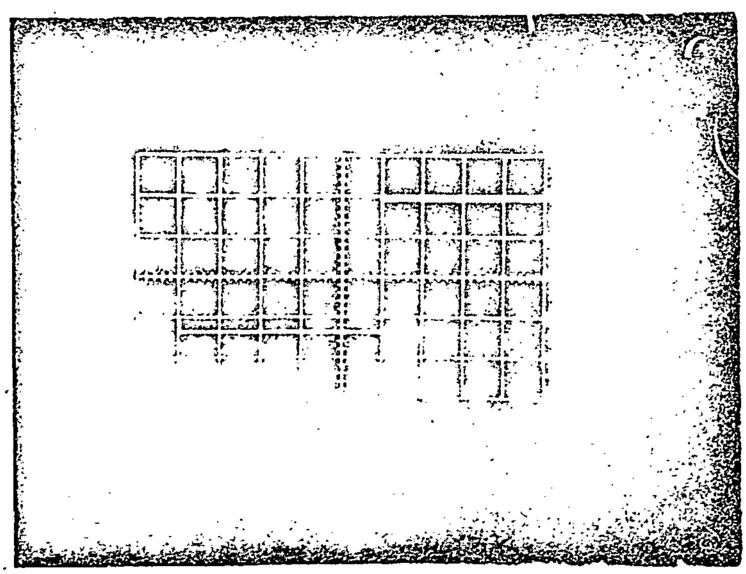
Figure 16 5KV pulse, 1 second



→ .2 sec/cm

↓ 20 mA/cm

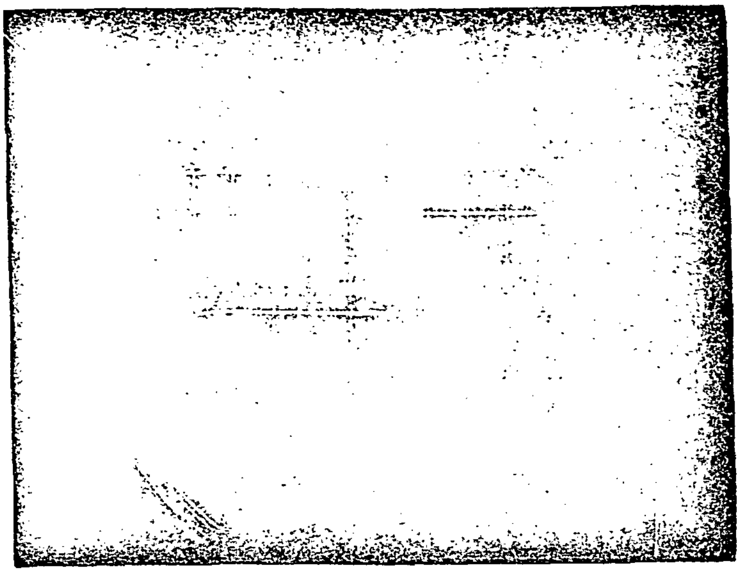
Figure 17 - 10 KV Pulse, 1 second



→ .2 sec/cm

↓ 20 mA/cm

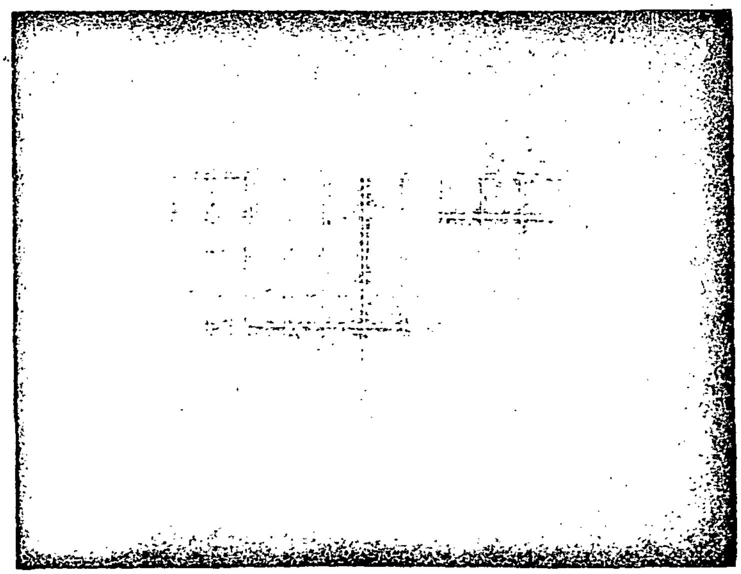
Figure 18 - 20 KV Pulse, 1 second



→ 1 sec/cm

↓ 20 mA/cm

Figure 19 - 5 KV Pulse, 6 seconds



→ 1 sec/cm

↓ 20 mA/cm

Figure 20 - 10 KV Pulse, 6 seconds

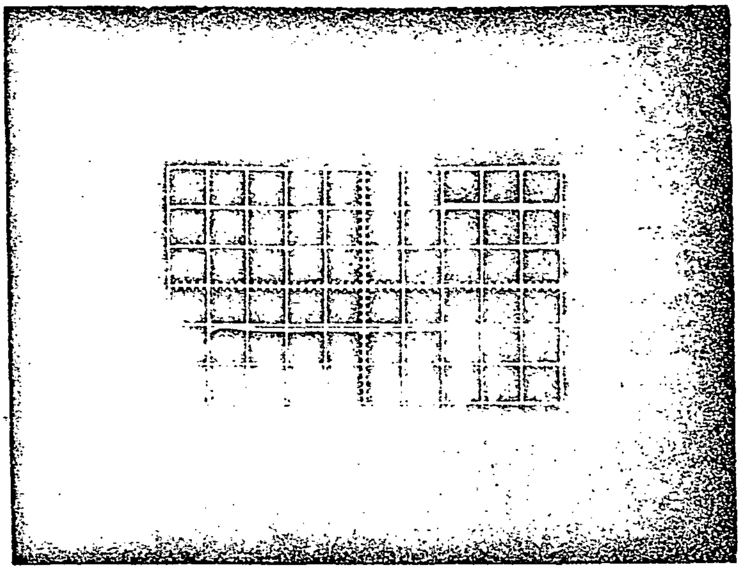


Figure 21 - 20 KV Pulse, 6 Second

Also of interest was the response during the rise of the pulse and a typical fast trace is shown in Figure 22.

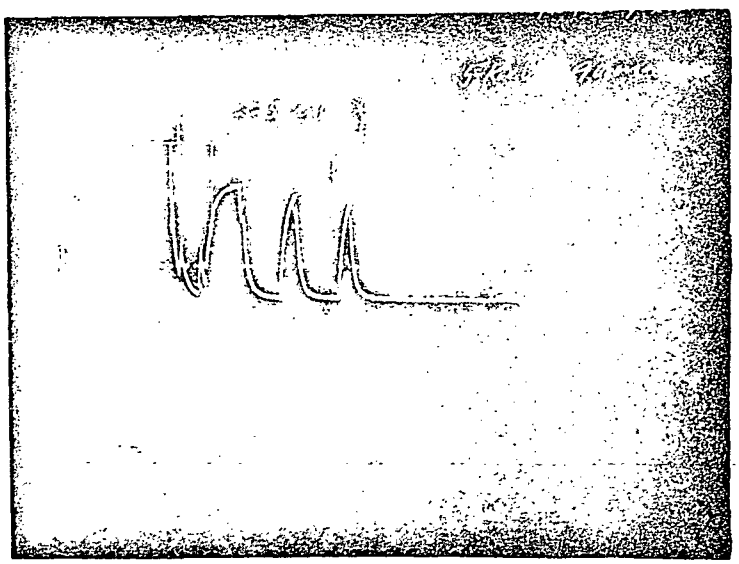


Figure 22 - Pulse Rise Shape

This photo indicates a considerable distrubance on the rise of the pulse, but this was determined to be traceable to contact noise on the relay used to program the gun on and off. Both prototypes displayed the same phenomena.

Calibration of the average target current as recorded on the photographs indicated that only about 75% of the H. V. power supply return current was being received on the target plate. An investigation showed that even though the primary beam was small enough to be completely on the target, about 25% of the return current was on the rest of the vacuum chamber.

An investigation, both theoretical and experimental, indicated that a large amount of secondary electrons with energies greater than 22.5 eV would be produced with primary electrons greater than 5 KeV and also reflected primary electrons at full energy would result. An experiment involving determining the collection efficiency of the target vs bias voltage up to 600 V was conducted with the results shown in Figure 23.

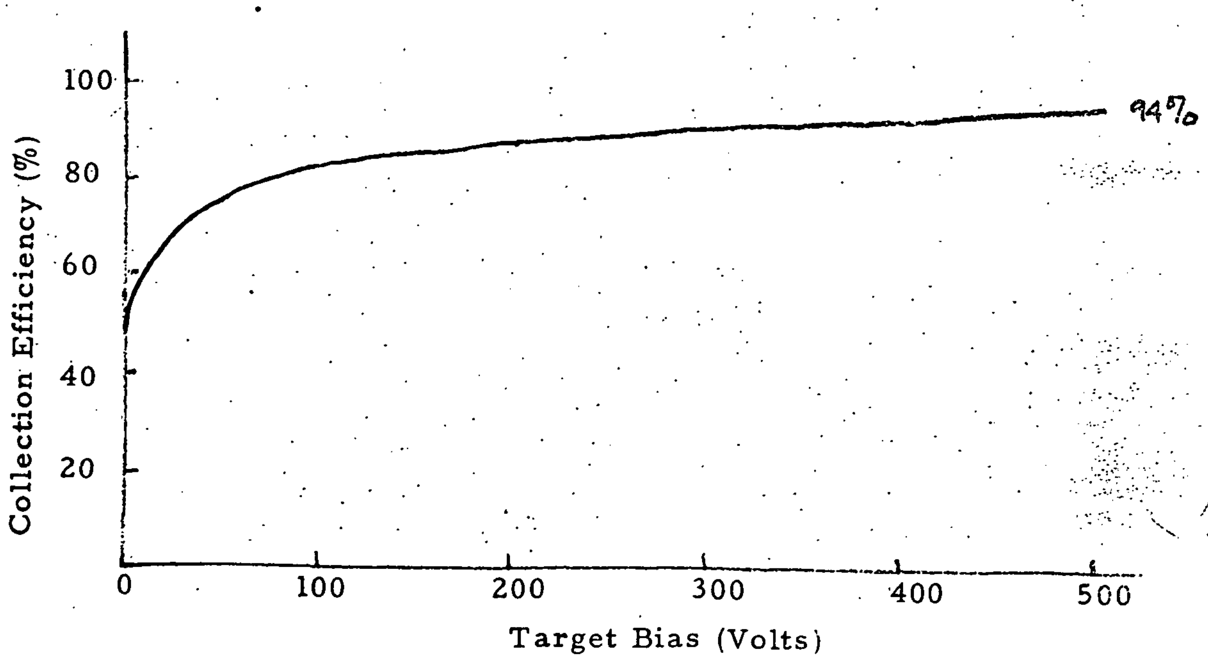


Figure 23 - Target Efficiency

The curve found experimentally agrees with the literature, not only with respect to true secondaries, but also to the expected number of reflected primary electrons as only about 95% c llection efficiency is obtainable at 600 V bias. The number of expected reflected primary electrons is ~5%.

First Anode Characteristics

Since during the original inspection of the first gun (serial #1) it was discovered that the first anode behaved like a negative impedance under certain operating conditions, special care was taken during the open gun tests to determine the actual operating characteristics of the first anode. The resulting data is shown in Figure 24.

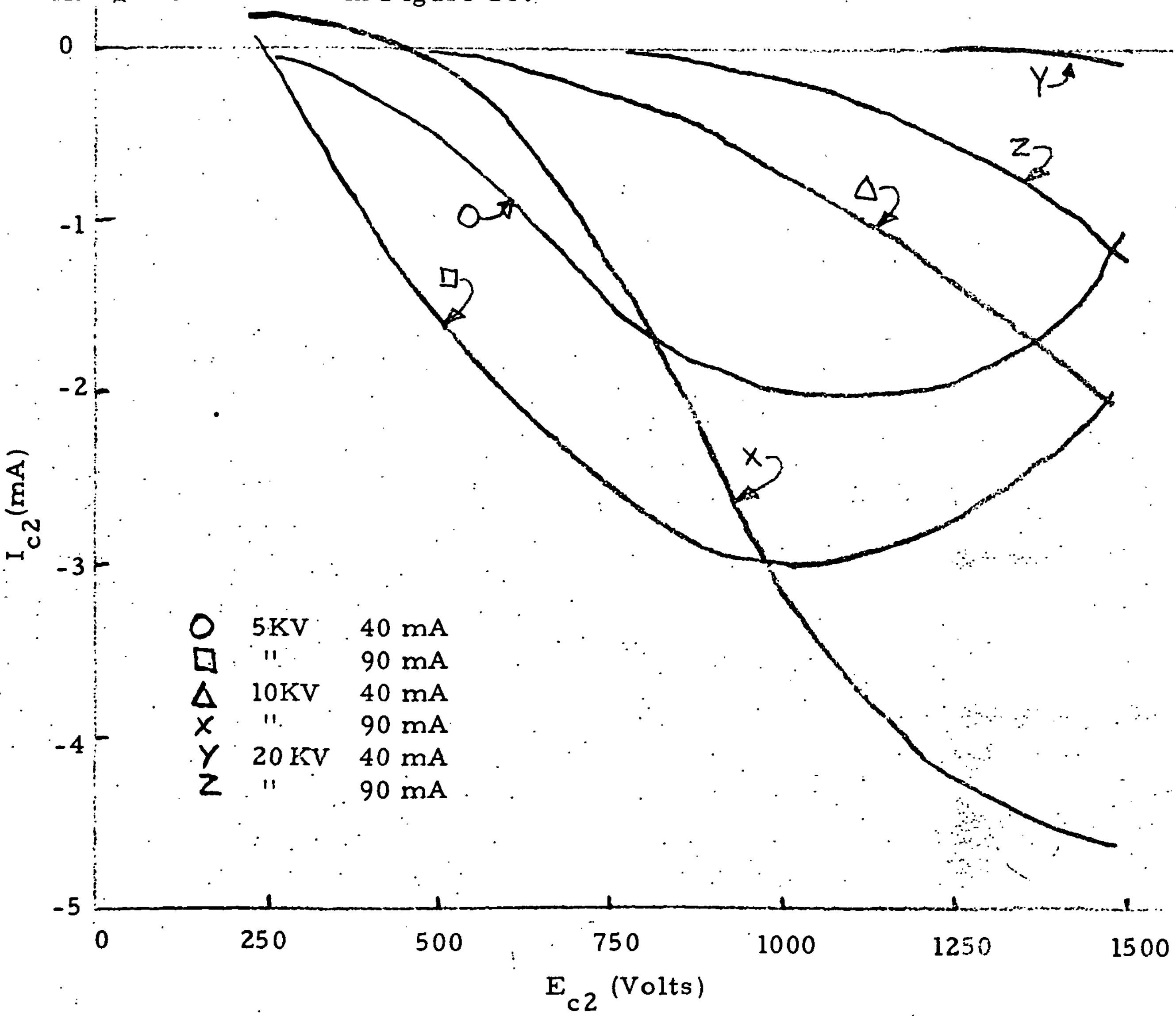
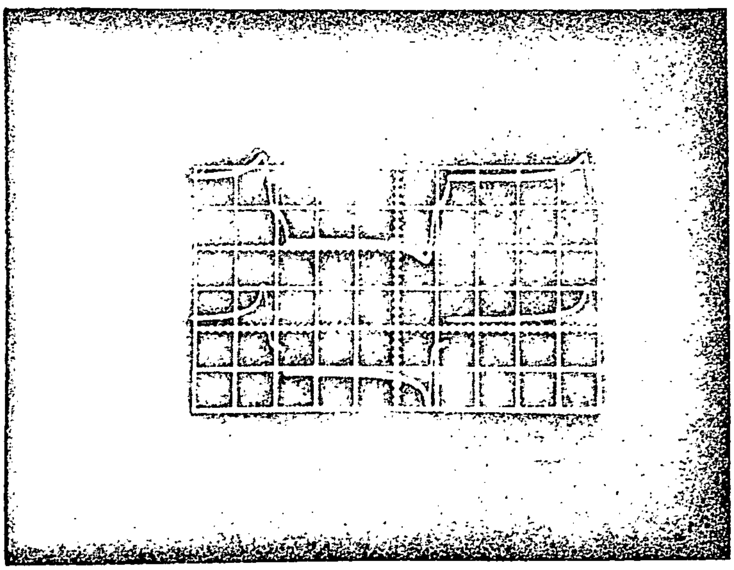


Figure 24 - First Anode Characteristics

Although we did not get good data on the second anode current, it was noted that it was normally less than lmA except when the first anode was highly into the negative current region, where the second anode would increase to the order of 10 mA.

Other experiments:

It was necessary to determine the feasibility of operating the heater from a 10 KHz square wave. Since the heater was constructed from a helix, it was thought that the inductance might be too high. Time constant measurements with a GR impedance bridge, however, indicated that one might expect the order of 2 μsec time constant when the heater was warm ($R \sim 5\Omega$, $L \sim 10\ \mu H$). The heater was tested with a waveshape similar to the expected waveform to be used on the flight package. The resulting current waveshape is shown in Figure 25.



↑ 10 v/cm

→ 10 μsec/cm

↑ 2.5 A/cm

Figure 25 - 10 KHz Heater Drive

Lifetime studies:

Both prototype guns were tested for lifetime capabilities, the tests were performed at an accelerator voltage of 20 KV and a cathode current of approximately 90 mA. The guns were pulsed at 50% duty cycle with about a 5 second pulse length.

After a period of about 30 minutes, the guns would begin to decay in output amplitude down to almost no output after one hour. During this time the base vacuum pressure was noted to rise from 1×10^{-6} torr to as high as 5×10^{-6} torr. Both guns displayed the ability to recover their output after a period of pumping with the filament on at reduced power. (Usually overnight.)

Conclusions:

A number of areas of concern are evident in the foregoing results. The first of these is the apparent weakness of the vacuum pinch-off with respect to power density, as compared to the rest of the endcap. Since the normal routine of operation calls for the electron guns to be checked out on the payload by a "ground-check program", one must be concerned with the maximum energy that can be imparted to the endcap under any condition, including system fault, in the closed mode.

Based on analysis of the most probable areas of failure, it is deduced that up to a 6 second pulse at full power might occur (corresponding to 10 KJ on the endcap). Discussions with the manufacturer point out that the end-cap will reach 250° C with only 0.25 watt average power and that temperatures greater than 600°C are serious. It is useful to indicate that these discussions are relevant to operation of the endcap in vacuum as would exist when the payload nosecone is in place, with little or no conductive heat sinking available. Obviously extreme care is necessary to prevent such a fault from occuring. Assuming that the system programming can be accomplished with satisfactory protection, then the only concern will be the reliability of the pinch-off to handle low average power (the order of 1 watt total on the endcap assembly).

There are two simple solutions to the problem which involve minor changes in the endcap design. Figure 26a shows the existing design and Figures 26b and 26c show possible alterations.

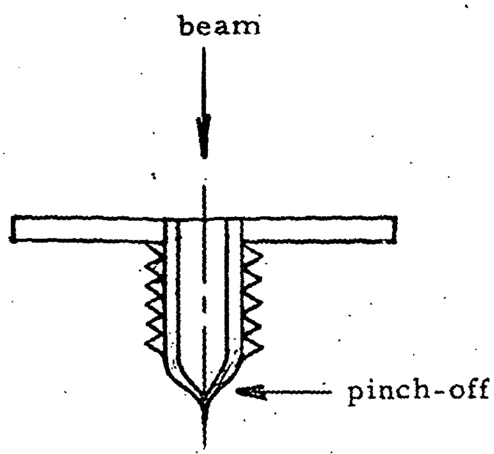


Figure 26a - Existing Endcap Design

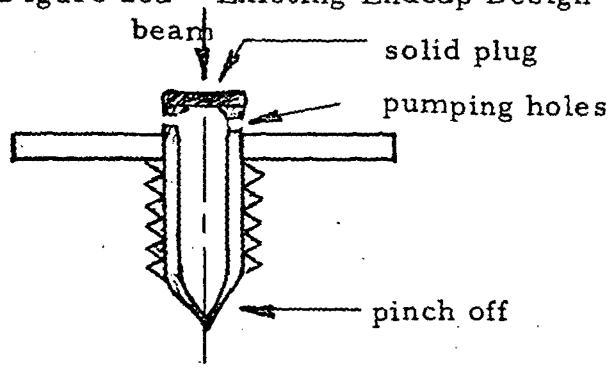


Figure 26b - Alternate Design A

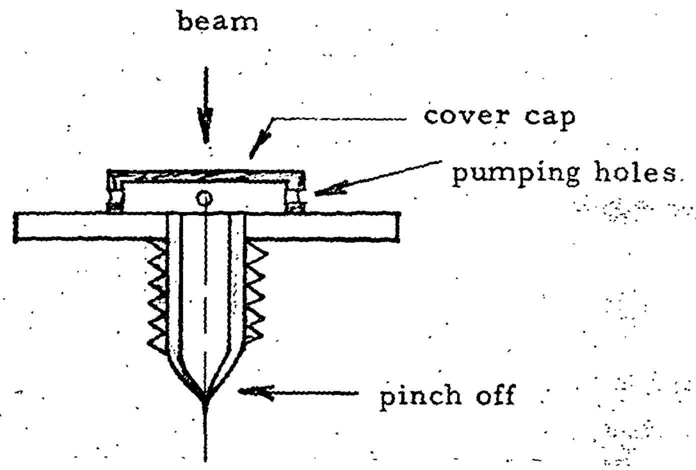


Figure 26c - Alternate Design B

Since changes in design at this particular point in time will possibly cause delays in future deliveries as well as cost increases, an effort to determine the necessity of any change is in order.

A possible method of arriving at a decision on this situation would be to determine the uniformity of construction of the pinch-off from gun to gun as compared to the failed unit by X-ray analysis. If it can be shown that other units have greater material thicknesses in the critical area, then a change in construction is probably not necessary. However, if a good degree of uniformity exists between units, then a recommendation to change the design will certainly be necessary to insure reliability.

In order to insure that a "no change" decision is correct, however, an investigation involving accurate measurements of thermal stress levels on all areas of the endcap assembly will be necessary. Such work would be beyond the scope of the present investigation.

The second area of importance is the electron-optical characteristics of the gun. There are two distinct modes of gun operation suggested by Figure 15. The first is a constant bias on the first anode and the second is a constant ratio between the first anode bias and the second anode bias. Figure 27 shows how these modes affect the electron-optics of the gun. It can be seen easily that the constant ratio mode yields almost a constant output beam angle. A decision as to which mode of operation best fits the needs of the experimenter must be wieghed against the methods of bias in which the first anode behaves in general like a negative impedance.

Before attempting to analyze the operational use of the gun as a "black box" device (in terms of the optics of the output beam), it is useful to hypothesize about the reasons behind the negative behavior of the first anode, thus the third and perhaps most important, area of concern arises.

The most probable cause for electron emission at the first anode is secondary emission. Since most metals have peak secondary-electron emission coefficients which are not much greater than unity, it is suspected that high

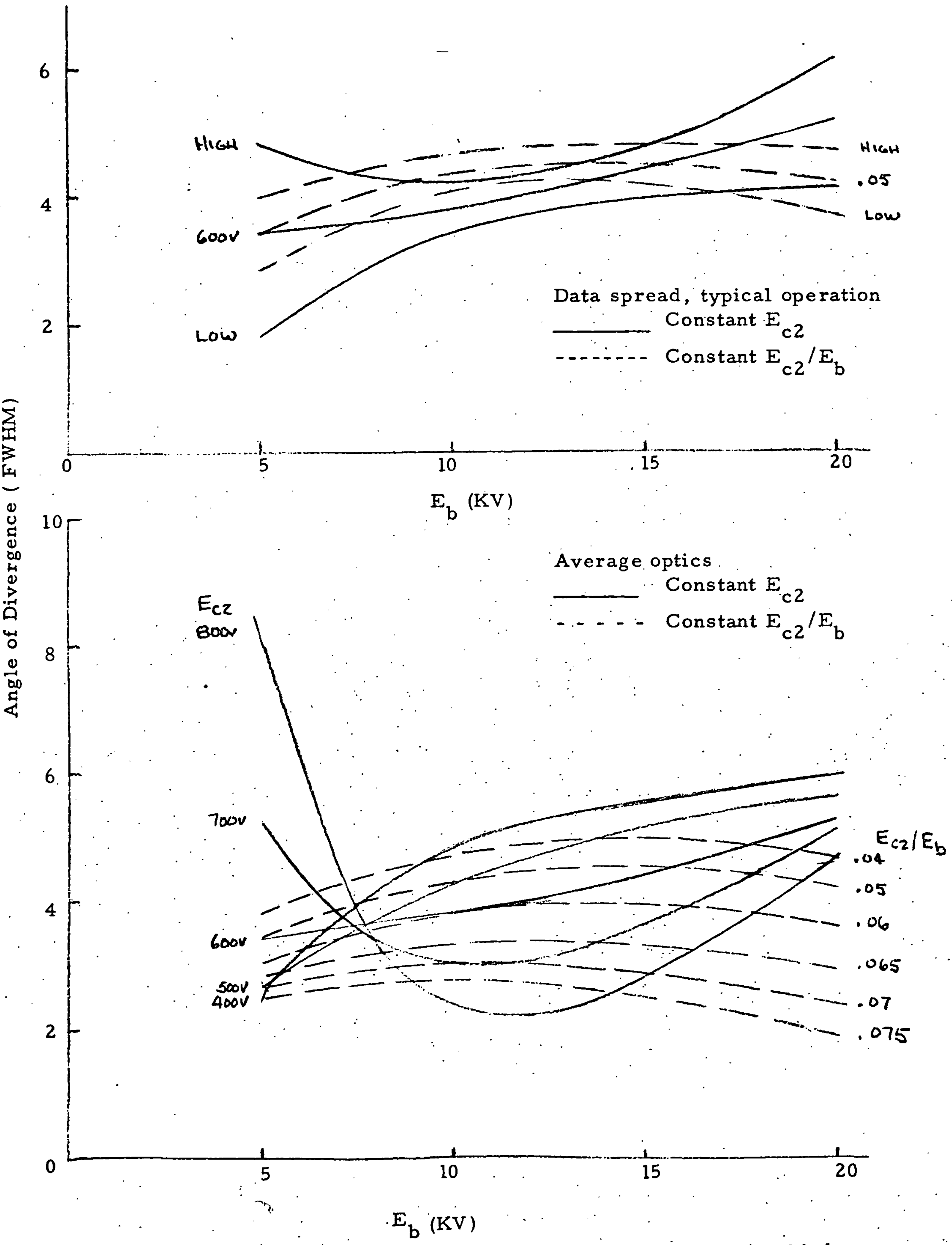


Figure 27 - Angle of Divergence vs Operating Mode

secondary emission yields would have to be derived from some oxide being present on the surface. This is not necessarily true, however if one takes into account the flancing incidence of the primary beam. (see Figure 28). Bruining* shows that as the angle of incidence goes from 0° (at normal incidence) to 90° , the emission coefficient increases exponentially. Therefore values much greater than unity can be easily achieved without the presence of oxides of things like rarium or strontium (from the cathode). The presence of barium alone (not in oxide form) would be insufficient to yield coefficients greater than unity (~ .83 max).

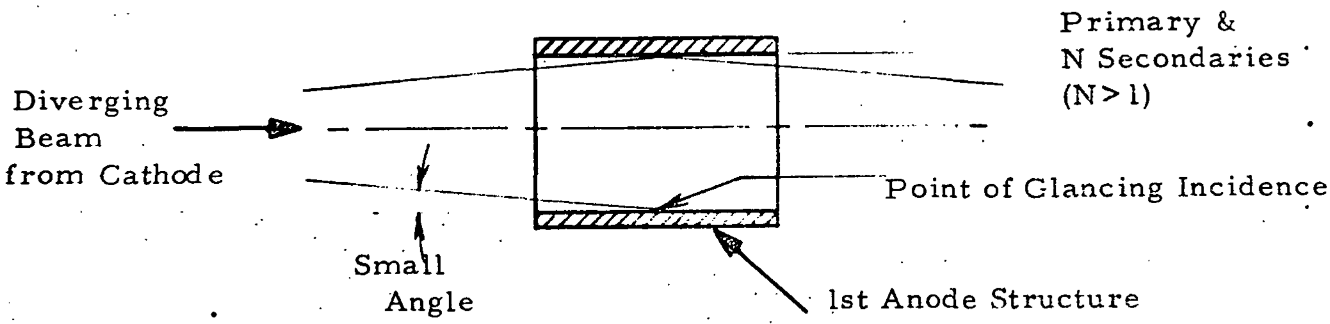


Figure 28 - Secondary Emission at Anode 1.

Observation of the surface of the first anode with a micorscope yielded information about the surface as to whether or not the presence of a rough surface would nullify the high yield gained from lancing incidence. Although severe tool marks were found, most of the surface was relatively smooth, thus substantiating the probability that metal alone could be responsible for the observed results.

Since an intuitive dislike of having to operate with a negative impedance generates the need to further analyze and correct the causes of same, more studies should be performed to prove or disprove the foregoing hypothesis.

* Secondary Electron Emission, Bruining, H.McGraw Hill-1959 pp 100-109

Lack of time, again, does not permit this. Therefore, provided that the negative impedance can be handled satisfactorily, the use of the gun as a "black box" with certain inputs to obtain the required output is in order.

This leads to the final aspect of the third problem - how to supply the first anode bias. There are three distinct possibilities:

1. Separate Converter
2. Tapped High Voltage Bleeder
3. Zener Stabilized H. V. Bleeder

The use of a converter puts complications on the flight package design because of increased parts count, but provides the flexability of being programmable, thus allowing either mode of operation (fixed voltage or fixed ratio). The tapped high voltage bleeder is the simplest approach, but allows a problem to develop- that of runaway on the first anode. This is true since the negative impedance will cause the anode bias to increase as the current increases, which in turn causes a further increase in the bias and so on. This is evident from the curves in Figure 24. The advantage of the tapped bleeder is fixed ratio operation, at the sacrifice of the heavy bleeder current necessary to stabilize the runaway condition. The third approach satisfies the condition of simplicity and fully stabilizes the first anode bias at the sacrifice of being restricted to fixed voltage operation. Figure 29a shows how the zener/stabilized bleeder would be implemented. Figure 29b shows an alternate appreach to the method in Figure 29a which allows some degree of programability with minimum parts increase.

Obviously the choice of fixed voltage or fixed ratio operation is quite interrelated between the demands of the experiment and the method of obtaining the first anode bias. The fixed voltage method may be the simplest to provide stabilization on the first anode whereas the tapped bleeder would be more reliable, due to possible zener diode failure from high voltage surges. Assuming that adequate protection of zeners can be implemented, then the zener-bleeder combination is favored due to its ability to hold stable voltages under the negative impedance condition. If fixed ratio (constant angle) is determined to be important, then the circuit of figure 29b may be used.

A further area of concern is lifetime and cathode poisoning. Guns

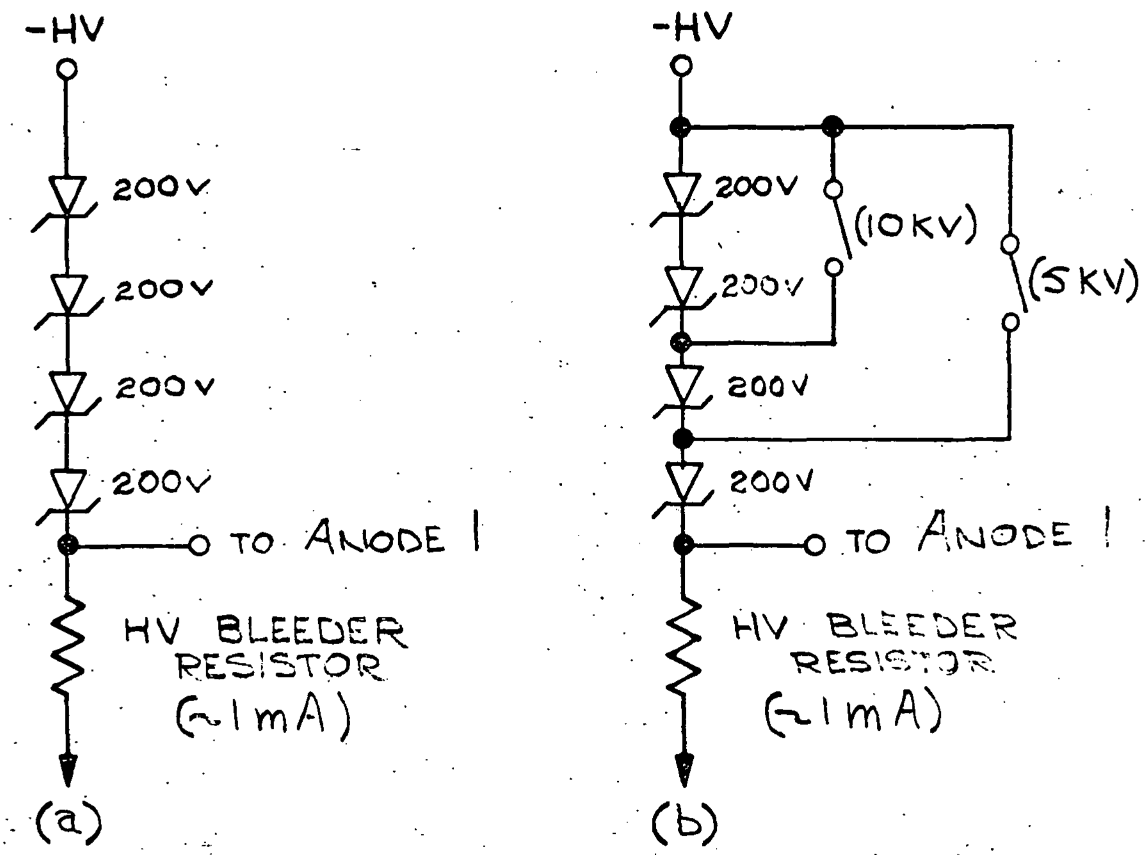


Figure 29 - Methods of Anode One Biasing

of this type are intended to be operated in a "clean" vacuum. However, once they are opened to their operating environment, a "clean" vacuum is usually not available because of outgassing and attitude control systems. This means that the cathode must be resistant to poisoning over the length of the mission. Controlled tests were not performed during the experiments outlined in this report to determine the exact characterisitics of the cathode being presently used. Appendix E contains a published report by the Machlett Laboratories concerning the phormat cathode being used and indicates greater lifetime expectancy under normal (closed tube) conditions than that achievable on earlier models (ie EE-65).

Further results in favor of adequate lifetime capabilities are: Gun #3 was recovered from poisoning with SF_6 by reactivation. Both guns tested ran for 30 minutes continuous pulsing before deterioration in an unclean vacuum with recoverability.

The mention of an unclean vacuum system is difficult to substantiate with proven fact except that (1) the system pressure was never better than 1 x 10^{-6} torr with LN_2 in a system that should easily reach 10^{-7} torr without LN_2 and (2) the test system originally contained a mercury pump which has proven back streaming difficulties as evidenced by visible Hg in the main chamber. These two points are felt necessary enough to indicate that the test vacuum chamber was not "clean" at all and did provide high level of contaminates including at least some Hg. Other contaminates which may have been present are unknown as to their constituents.

More work in the area of cathodes is clearly necessary from these sketchy results and should be performed in an ultraclean vacuum system (Vac Ion or similar) with possibility of full bakeout considered. This would allow control of poisonability tests without being affected by unknown system contaminates.

It is concluded however, that although the experimental program is obviously lacking in detail concerning certain areas, that the gun will be satisfactory for flight use with some future changes in design being probably necessary for continued reliable use.

APPENDIX A

Serial Number__________

Specification I/ML-EE65-

Revision 3

Date 10/21/70

Quality Assurance Provision
for
Acceptance Testing
of
Electron Guns, Electron Accelerator Package

Contract NAS 9-10399

IPC WA - 89107

Prepared by W. E. Starks

Approved R. V. James

R. V. James

ION PHYSICS CORPORATION

IPC

A Subsidiary of High Voltage Engineering Corporation

BURLINGTON, MASSACHUSETTS

1.0 Scope

This procedure defines the acceptance tests to be performed on the Electron Guns, Electron Accelerator Package, in order to verify the operating condition and quality of performance

2 0 Applicable Documents

The following documents are applicable to the equipment for which the tests described in this procedure are intended:

IPC Drawing Numbers

C - 1055-002 (sheets one and two)

3.0 Test Requirements

3.1 General

These units will provide a 100 milliampere electron beam at a maximum energy of 20 KeV operating at a 33% duty cycle in output power for a minimum lifetime of 10 minutes. The ensuing tests will not involve testing units to these limits as destructive testing would be necessary to achieve this information.

3.2 Test Equipment

The following test equipment is required for the tests described in this procedure:

(1) Oscilloscope, Tektronix Model 536 with 2 IAl's or IA2's plugin units, or Tektronix Model 502A used X-Y.

(2) Camera, Tektronix Model C-19 or Tektronix Model C-27 with 3000 speed Polaroid Film (black & white).

(3) Power supply, Kepco Model ABC, 0-10 volts, 0-3 amps

(4) Power supply, Sorenson Model QRB 40-.75, 0-40 volts, 0-750 mA

(5) Picoammeter, Keithley Model 414

(6) Simpson Multimeter, Model 260-5M, or RCA model WV98C VTVM

(7) Hartman and Braun Wheatstone Bridge

(8) High voltage power supply, Del Electronics Model 25-200-1, 0-25KV, 0 - 200 mA or Del 25-50-1

(9) Power supply, Kepco Model ABC 0-1500V, 0-10 mA.

(10) 30V Ramp-generator B 1055-042

(11) High voltage power supply, Spellman Model RHR 50PN150, 0 to 60 KV, 0 to 5 mA

(12) EE-65-1 Test Fixture

(13) Fan for end cap aircooling

(14) Binocular Microscope or 3X magnifier

This equipment must be maintained on a calibration cycle of once every six months or oftener.

3.3 Test Conditions

3.3.1 Environmental Conditions

Perform all inspection in semi-clean room when possible. In transporting tube to and from clean room, keep in a clean plastic bag and cardboard box to prevent exposure to general plant atmosphere. Handle only with lint free silk gloves or talc-free rubber finger cots.

Tests outlined in sections 6.0 and 7.0 shall be performed with the test unit mounted in item 10 of section 3.2 with the fixture contained in one (1) atmosphere of dry sulphur hexaflouride gas (SF_6).

3.3.2 Power Requirements

The following power sources are required for the tests described in this procedure:

(1) 115 Vac, ± 10%, 60 Hz, 0.5 KVA

(2) 208 Vac, 3Ø, ± 10%, 60 Hz, 5 KVA

3.3.3 Test Sequence

All tests must be performed in the order in which they are given in this procedure.

4.0 Visual Inspection

Inspect each unit visually for defects in workmanship and handling. If there is any defect, enter the letter "R" (rejected) in the appropriate space below: if no defect, enter the letter "A" (accepted). In either case, the inspector must sign off the test record. Is the package sealed? (Yes or No) __________ ______

(date) (initial)

TEST DATA

ITEM		A/R	Date	Initial
4.1	Breakseal Tabs-Inspect Brazing for any pull-away of tabs. Reject if tabs are not tight. Do not pull on tabs this is visual insp. only.	______	______	______
4.2	Breakseal Metalized Band-Inspect for pits, holes, or cracks with a binocular microscope.* Reject if any.	______	______	______
4.3	Anode two to cap ceramic. Inspect for cleanliness. Reject if dirty.	______	______	______
4.4	Anode two flange. Inspect sealing surface for scratches and nicks with a binocular microscope.* Reject if any.	______	______	______
4.5	Anode one to Anode two ceramic. Inspect for cleanliness. Reject if dirty or contains markings of any kind.	______	______	______
4.6	Anode one contact flange. Inspect for sharp edges or protrusions. Reject if any.	______	______	______
4.7	Grid one to anode one ceramic. Inspect for cleanliness. Reject if dirty.	______	______	______
4.8	Grid one contact flange. Inspect for presence of serial numbers or any visual dents. Reject if missing or dented.	______	______	______
4.9	Filament to cathode annular space. Inspect for cleanliness. Reject if dirty.	______	______	______

* 3X magnifier may also be used.

4.10 Filament and cathode contacts. Visually inspect for roundness and concentricity. Reject if obviously out-of-round or dented. ______ ______ ______

4.11 Measure and record dimensions "A" thru "X" per drawing IPC-C-1055-002 sheet number one. Check if out of tolerance and reject. ______ ______ ______

DIMENSIONS IN INCHES

	Minimum	Actual	Maximum	✓	A/R	Date	Initial
A	.592		.632				
B	.833		.863				
C	1. 105		1.135				
D	1. 425		1.455				
E	1. 784		1.824				
F	.049		.055				
G	.660		.690				
H	.110		.145				
I	—		1.300				
J	.210		.220				
K	.310		.325				
L	.655		.665				
M	1. 194		1.206				
N	1. 660		1.668				
O	---		.010 TIR				
P	---		.015 TIR				
Q	---		.025TIR				
R	.250		.325				
S	.045		.125				
T	.120		.130				
U	.031		.124				

					A/R	Date	Initial
V	.062	_____	.125	___	_____	_____	_____
W	1 .015	_____	1.035	___	_____	_____	_____
X		_____	1.323	___	_____	_____	_____

5.0 Static Electrical Tests

5.1 Measure cold resistance of the breakseal band with a Hartman and Braun Wheatstone Bridge. Value ____ohms.

Reject if greater than .5 ohms or less than .1ohms. _____ _____ _____

5.2 Measure cold resistance between cathode and filament with a Hartman and Braun Wheatstone Bridge. Value _____ohms.

Reject if greater than 1.0 ohm or less than o.1 ohm. _____ _____ _____

5.3 Measure resistance between the cathode and grid one with a Simpson Multimeter Model 260 on the 10,000 ohm scale. *

Value __________ ohms.

Reject if less than 10 megohms. _____ _____ _____

5.4 Measure resistance between grid one and anode one with a Simpson Multimeter Model 260 on the 10,000 ohm scale. *

Value __________ ohms.

Reject if less than 10 megohms. _____ _____ _____

5.5 Measure resistance between anode one and anode two with a Simpson Multimeter Model 260 on the 10,000 ohm scale. *

Value __________ohms.

Reject if less than 10 megohms. _____ _____ _____

5.6 Measure resistance between anode two and the cap with a Simpson Multimeter Model 260 on the 10,000 ohm scale. *

Value __________ ohms.

Reject if less than 10 megohms. _____ _____ _____

6.0 Hipot DC Testing

6.1 Test Configurations

The configurations for these tests are shown in figures 6.2 and 6.3.

* RCA model WV98C VTVM on the one megohm scale may also be used.

The unit being tested shall be mounted in test fixture EE65-1, and contained in one atmosphere of dry sulphur hexaflouride gas (SF_6).

6.2 Anode Two to Anode One Hipot Testing

Test configuration in Figure 6.2. Test Procedure:

Hipot in dry SF_6 environment at 1 atmosphere pressure

Increase voltage slowly to 20 kv then proceed in 2 kv steps

Hold voltage for 30 seconds without breakdown at each step from 20 - 28 kv.

At 30 kv hold voltage for 5 minutes. After this period if a gun will not hold 30 kv for at least 30 seconds, it will be rejected.

During 5 minute run record voltage and current every 1 minute and note the number of breakdowns, if any.

During 30 second run record voltage and current at the end of period. Also record the number of breakdowns at each level.

Voltage (KV)	Current (μ amps)	No. of Breakdowns
20	________	________
22	________	________
24	________	________
26	________	________
28	________	________
30	________	________

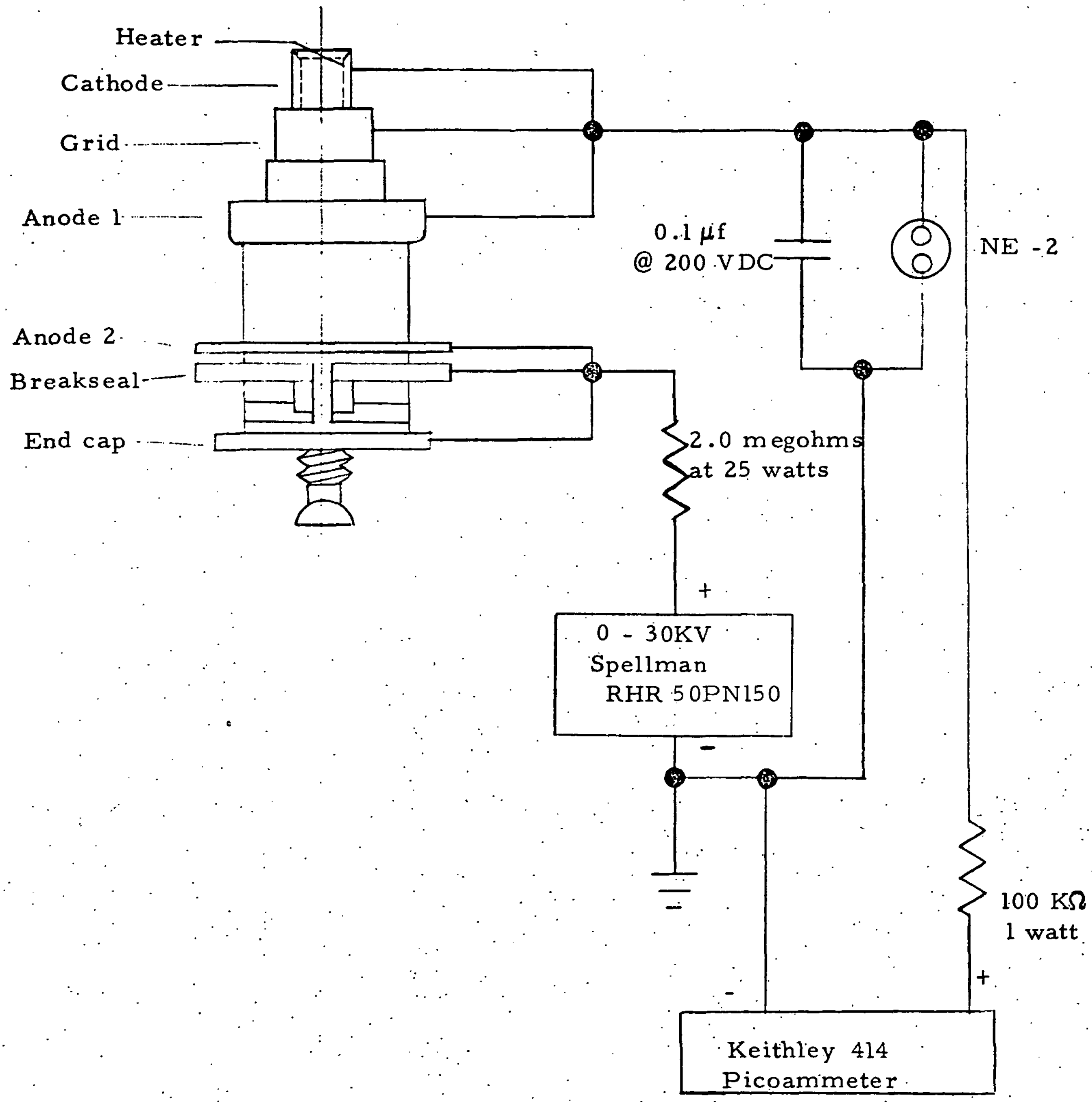
Minute (5 min.run)	Current (μ amps)	No. of Breakdowns
0	________	________
1	________	________
2	________	________
3	________	________
4	________	________
5	________	________

Final 30 second test:

No. of breakdowns ____________

Reject if any

________ A/R ________ Date ________ Initial



Anode Two / Anode One   Hipot Configuration

FIG. 6.2

6.3 Anode One to Grid One Hipot Testing

Test configuration in Figure 6.3. Test Procedure:

Hipot in dry SF_6 environment at 1 atmosphere pressure.

Increase voltage slowly to 1 kv then proceed in 200v steps

Hold voltage for 30 seconds without breakdown at each step from 1 to 2 kv.

At 2 kv hold voltage for 5 minutes. After this period if a gun will not hold 2 kv for at least 30 seconds, it will be rejected.

During 5 minute run record voltage and current every 1 minute and note the number of breakdowns.

During 30 second run record voltage and current at the end of period. Also record the number of breakdowns at each level.

Voltage (KV)	Current (nA)	No. of Breakdowns
1.0	______	______
1.2	______	______
1.4	______	______
1.6	______	______
1.8	______	______
2.0	______	______

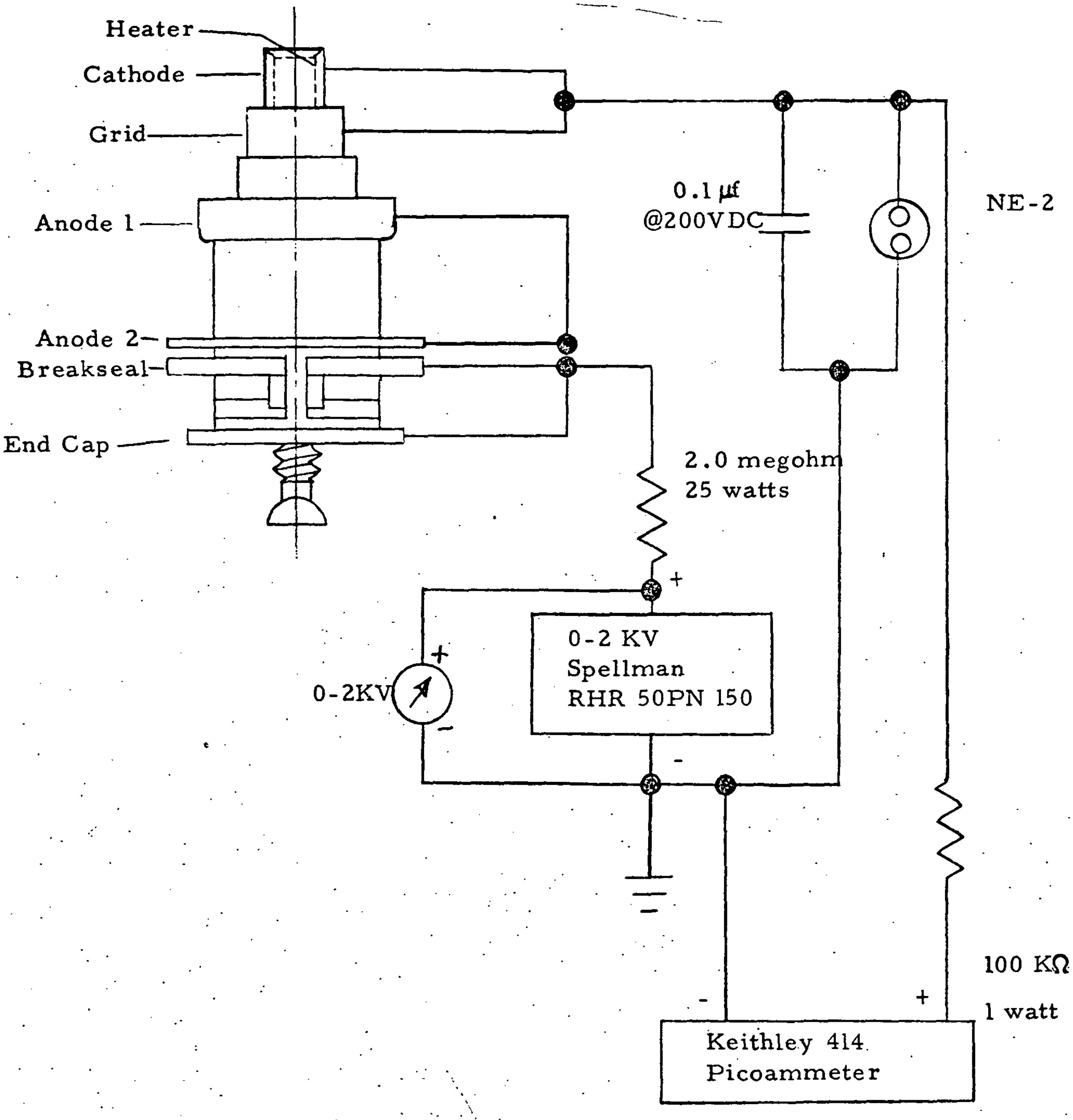
Minute (5 Min. Run)	Current (nA)	No. of Breakdowns
0	______	______
1	______	______
2	______	______
3	______	______
4	______	______
5	______	______

Final 30 second test:

No. of breakdowns ______.

Reject if any ______ ______ ______

A/R Date Initial



Anode One / Grid One Hipot Configuration

FIG. 6.3

7.0 Gun Transfer Characteristic Measurements

7.1 Test Configurations

The configuration for these tests is shown in figure 7.1. The unit being tested shall be mounted in test fixture EE 65-1, and contained in one atmosphere of dry sulphur hexaflouride gas (SF_6).

7.2 Filament Current Tests

Energize filament and determine filament current at 7.5 volts. Accept if current falls between 1.425-1.575 amps. Reject if current is less than 1.40 or more than 1.60 amps. Reject and hold if current is 1.4-1.425 or 1.575-1.6 for review by engineering and Q.C.

Current________________ Amps. __________ A/R __________ date _______ initial

7.3 Grid One Characteristic Measurement

Obtain oscilloscope record of plate-current-grid voltage characteristics for the following conditions with filament at 7.5 volts.

a) Anode two- cathode voltage 5.0KV ± 10%.
   Anode one - cathode voltage 250 V ± 5%.

b) Anode two - cathode voltage 10. 0KV ± 10%.
   Anode one - cathode voltage 500V ± 5%.

c) Anode two - cathode voltage 20. 0KV ± 10%.
   Anode one - cathode voltage 1000V ± 5%.

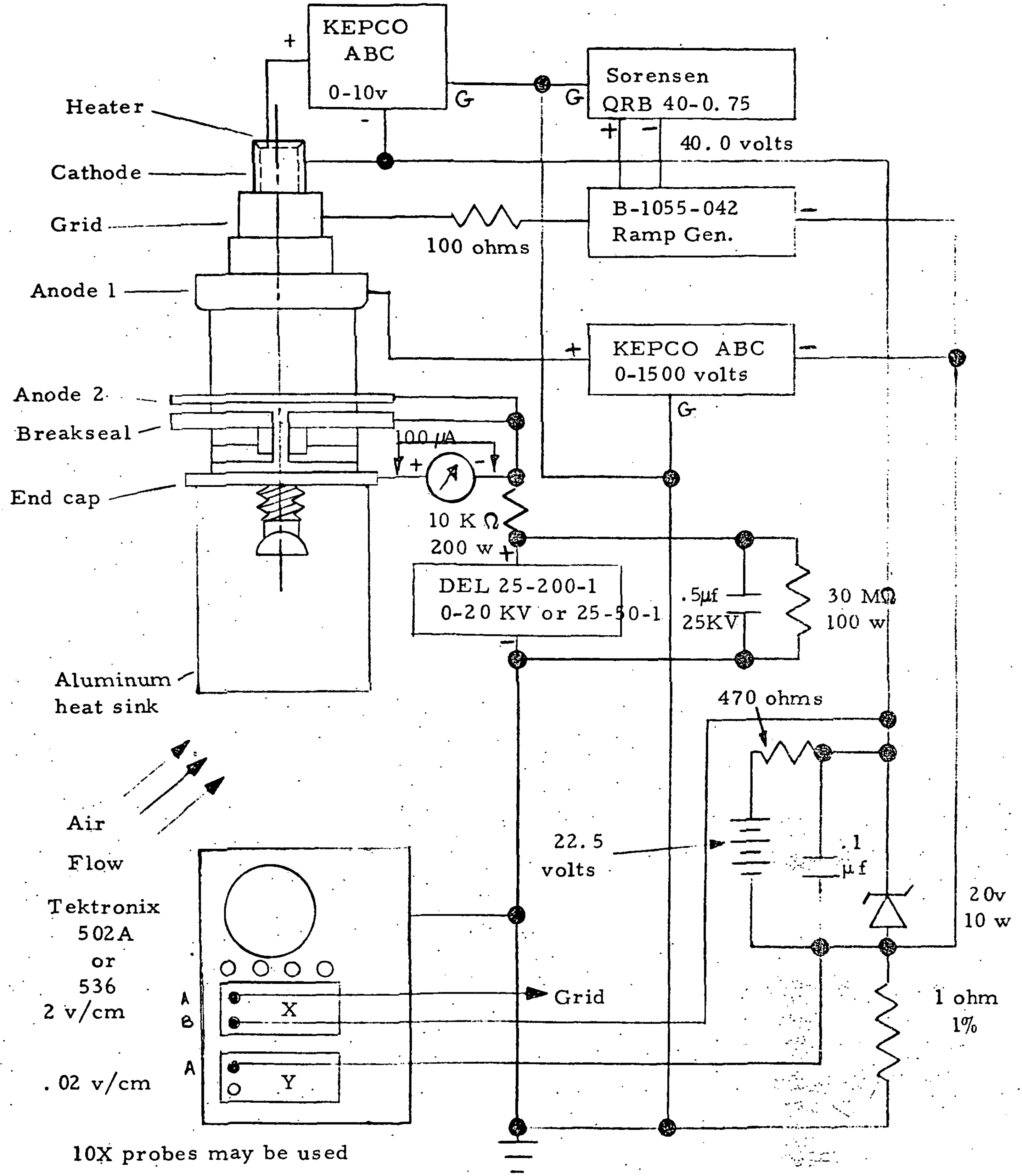
Test performed by manually triggering the 30 volt ramp generator. Do not exceed 10 sweeps on the gun in 1 minute. Be sure that the end cap is properly heat sinked as indicated in figure 7.1.

NOTE: For grid control characteristics to be acceptable at 20KV:

A. The grid bias required to obtain 100 ma return current must fall between -2.5 volts and +.5 volts.______Volts @ 100 mA

B. At 100 ma the mutual conductance (g_m) of the tube must fall between 18,200 and 24,600 micromhos. This number is derived by taking from the 20 KV photograph the grid voltage at 80mA (V_{80}) and the grid voltage at 100 mA (V_{100}) and inserting in the following formula:

$$g_m = \frac{20,000}{V_{100} - V_{80}} = \_\_\_\_\_\_ \ \mu\text{mhos}$$



Gun Transfer Charateristic Test Setup
FIG. 7.1

X____ V/cm

Y____mA/cm

5.0 KV

X____V/cm

Y____mA/cm

10.0KV

X_____V/cm

Y_____mA/cm

20.0KV

_____ A/R _____ date _____ initial

7.4 Grid One Cut-off Test

Test performed by switching B-1055-042 ramp generator to cut-off position. Also remove shorting clip from 100 μ amp meter. Record leakage current under conditions described in section 7.3 (c). Reject if greater than 5 μA.

Current _____________________ μA

_____ A/R _____ date _____ initial

Return switch on B-1055-042 ramp generator to ramp position and shorting clip across 100 μamp meter. Initial after completion.

_____ date _____ initial

8.0 Final Inspection

8.1 Remove from bench checkout unit and inspect for any changes in appearance - cracks, chips, tracks, evidence of overheating, etc., using a binocular microscope.*

Final Acceptance

Inspector ______________________ A/R

Quality ______________________ A/R

Program ______________________ A/R

8.2 Replace guns in their original boxes and mark the package accepted, or rejected. If rejected explain reasons in a few words. Inspector should sign and date each box upon completion of the above.

* 3X magnifier may also be used.

APPENDIX B

FAILED COMPONENT PART ANALYSIS REPORT

(COMPLETE THIS FORM IN BLOCK LETTERS)

3. REPORT NUMBER
11084B

1. DATE
8-31-70

2. REFERENCE
Contract NAS 9 - 10399 W/A 89107

OMPONENT PART NAME
Electron Gun Model ML-EE65-1 Serial #1

5. REPORTED REMOVAL CAUSE
Grid-cathode short, increase in filament current to 2 amps

6. FAILURE ANALYSIS METHOD EMPLOYED
Gun was opened by activation of the breakseal after a telephone conversation with W. H. Merritt of Machlett Laboratories for visual observation at the suggestion of Mr. Merritt.

7. FAILURE ANALYSIS RESULTS At IPC on 8-31-70
1. Holes in grid structure just inside cathode perimeter.
2. Melted grid wires shorted to cathode surface.
3. Cathode surface dark grey instead of normal white.

At Machlett on 9-1-70
1. Silver plating missing from end of pinch-off on the evacuation tubing.
2. Hole found in the pinch-off visible with the unaided eye.

8. COMPONENT PART FAILURE CAUSE
Failure caused by overheating of the pinch-off due to excessive energy dissapation as result of the test procedure levels. Temperatures greater than 800°C were present at the pinch-off as evidenced by the complete lack of silver plating. The developmen of an air leak resulted in the symptoms indicated in item 5, above.

WAS COMPONENT PART FAILURE CAUSE CONSISTENT WITH MODULE OR SYSTEM FAILURE/MALFUNCTION SYMPTOMS

YES ☐ NO ☐ NEOF ☐ (No Evidence of Failure) Not applicable

10. PRIMARY OR SECONDARY COMPONENT PART FAILURE?

PRIMARY ☒ SECONDARY ☐ NEOF ☐

11. COMPONENT PART FAILURE RESPONSIBILITY

DESIGN	☐	TEST ERROR	☒
FABRICATION	☐	NORMAL WEAROUT	☐
PART	☐	EXTERNAL	☐
WORKMANSHIP	☐	UNKNOWN	☐
HANDLING	☐	NONE	☐

OTHER ____________

12. CORRECTIVE ACTION RECOMMENDED
1. Test procedure I/ML-EE65-1 section 7.3 be changed to reduce energy dissipati by at least one hundred to levels attained by Machlett Labs during pulse testing (the order of 10 joules per test not to exceed 1000 joules per minute heat sinked). 2. Car to be taken in design of test and check circuits and procedures to insure safe operatic sealed with 100% confidence.

13. REMARKS
Failure occurred during testing under section 7.3 of inspection plan I/ML-EE 65-1

14. FAILED COMPONENT PART ANALYST'S SIGNATURE
William E Sla[illegible] Approved E. E. Har[illegible]

FAILED COMPONENT PART ANALYSIS REPORT

Operational Considerations

Ref: Failed Component Part Analysis Report 11084B

A Critical design review was held 3 September 1970 to ascertain whether the component (electron gun EE 65-1 prototype) test failure could affect the operation of deliverable payload during ground check-out and launch.

Attendees: Hansen, James, Starks, Weinschenk, Macklin

Items of Discussion:

1. A modification of the gun cap configuration was discussed to prevent the beam from impinging on the pinch off tube wall thin section.

   1.1 The impact of a change would not prevent thermal failure of the gun as the total thermal heat sink capability of the gun cap is not great enough to dissipate the energy present in full power test erroneously exceeding the 10 joule maximum energy level.

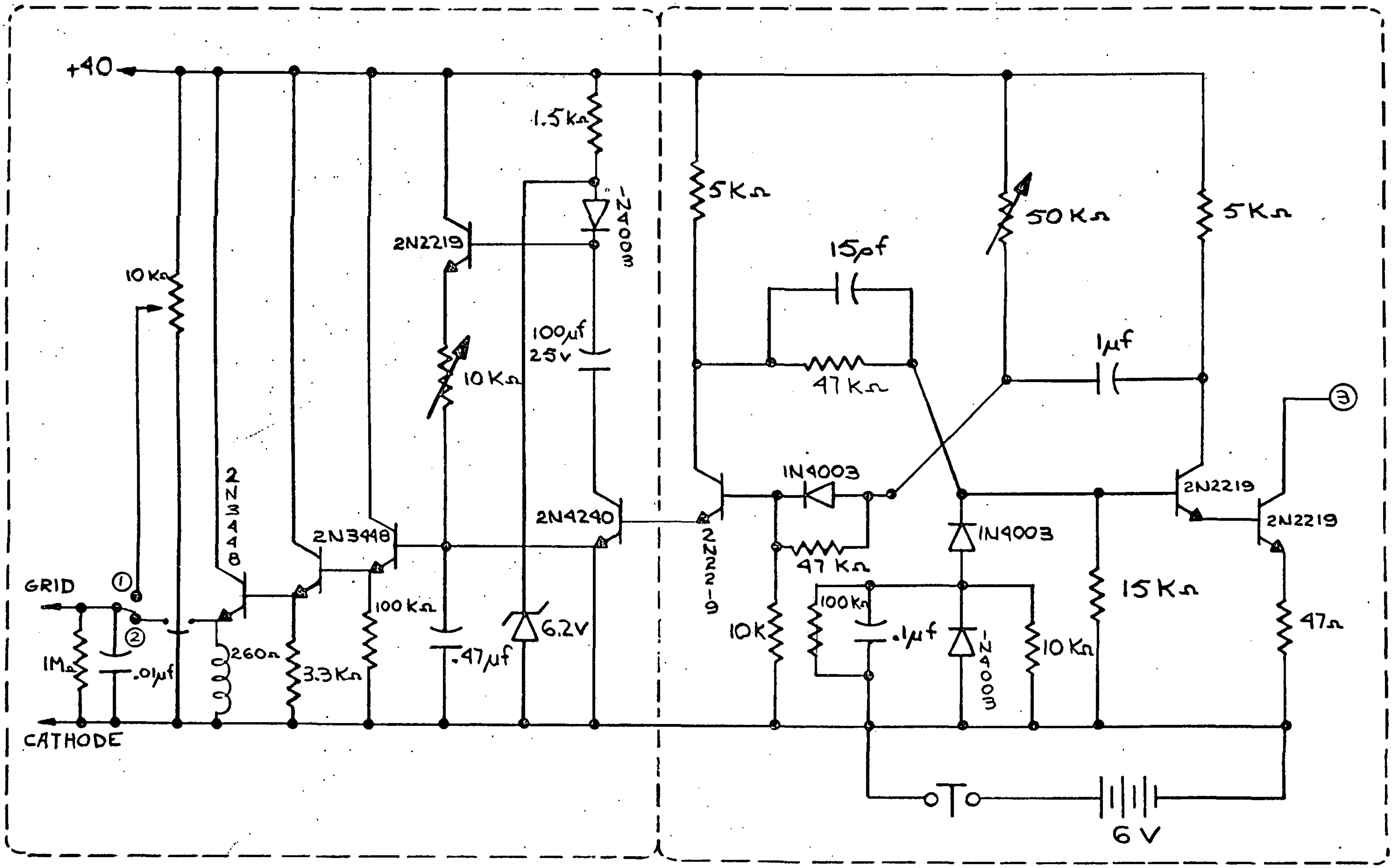
2. Action taken to prevent operational failure during ground check out.

   2.1 Design of a fail-safe ground check out program is being investigated.

   2.2 Implementation of the fail safe measure into existing program to be accomplished.

   2.3 No design change to gun cap is recommended or forthcoming at this time.

APPENDIX C

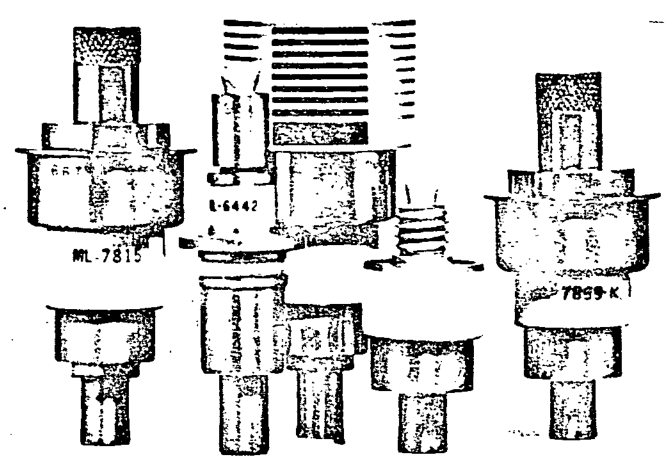


Appendix C - Grid Sweep Circuit

APPENDIX D

ATTACHMENT #4

The Machlett Laboratories, Inc. • 1063 Hope Street
Stamford, Conn. 06907 • Tel. 203-348-7511 • TWX 710-474-1744



ISSUED 10-68

Application Notes UHF Triodes Extended Life AL Series Tubes for Airline Operation

MACHLETT

General

The Machlett AL series of planar triodes for low-maintenance, low down-time airline operation are produced and tested to premium standards to insure extended life performance. This long life operation is a result of a combination of many factors including: stringent application of newly defined quality control standards; the use of the Machlett Phormat cathode employing improved cathode material; application of a testing schedule going well beyond military specifications; use of anti-corrosion plating (gold) to ensure excellent contact life and performance. Covered by an extended life warranty, these tubes are mechanically and electrically superior to the standard types,... in addition they will outperform the standard types under long-life conditions (i.e., reduced heater voltage) by a wide margin.

Filament Voltage: 5.7 V Operation

Any tube that will pass MIL-E specifications will operate at heater voltages in excess of 6.0 volts. Only those tubes with excellent cathode activity will operate at rated power for extended periods at less than 6.0 volts. The Machlett AL series tubes operate at 5.7 volts, nominal. It is imperative that this voltage level be maintained to insure that cathode temperatures are held at the level for which the heater design has been optimized. *Only by operating the AL series tubes at 5.7 volts, nominal, will the extended life capability be realized.* Factors defining the performance of AL series cathodes are described in the paragraph entitled "Phormat Cathode".

Anti-Corrosion Plating

To minimize contact loss and substantially eliminate arcing due to corrosion effects the Machlett AL series planar triodes are gold plated. Both tube and contact life will be enhanced, particularly where conditions favorable to corrosion exist.

Phormat Cathode

The Machlett Phormat cathode (a matrix cathode) employs a porous coating which provides an arc-resistant surface. Its high voltage stability, therefore, is excellent and its ability to maintain a clean tube interior is correspondingly good. Field gradients of 135 kV/cm and higher have been impressed between the grid and anode of the ML-7815 and ML-7815/AL and also to comparable tubes not using the Phormat cathode. While the standard cathodes were almost completely destroyed the Phormat cathode showed only a few arc marks — and yet still maintained its operating capability. (Modulator tubes such as the planar triode ML-8533 carry an 8 kVdc plate voltage rating.)

Deposited vs Sprayed Cathodes

The Phormat cathode has been in use in UHF planar tube types since its development by Machlett Laboratories in 1960. The high reliability of this cathode under extreme voltage conditions has made possible its use in grid pulsed applications. The use of this cathode type at high frequencies, where transit time increases the back-bombardment of the cathode, gives the Phormat cathode great advantage as compared with the standard sprayed cathode.

The structure of the cathode consists of a metal base on which a porous layer of nickel is deposited by electrolytic and cataphoretic deposition*. This cathode is sprayed as a regular emitter, but it presents a rough surface where the triple carbonate coating (BaSrCa) CO_3 can more easily obtain the required donors increasing the uniformity of emission of the layer, thereby avoiding the "patchy" emission characteristic of standard emitters. This nickel "sponge" provides at the same time a very fast heat transfer, reducing the effects of the backbombardment on the cathode at high frequencies.

Another major advantage of the Phormat cathode in pulsed applications is its ability to reduce the adverse effects of arcing within the tube. When arcing occurs in a standard sprayed cathode, large segments of the cathode layer tend to lift from the metal base resulting in catastrophic failure whereas in the Phormat structure only a localized area is affected and tube life is unimpaired.

Quality Control and Tube Testing

The Quality Control operation associated with the Small Power Tube Product Line — which produces the Airline Quality planar triodes — operates more as a continuous process control than a check and inspect procedure. Under a continuous feedback control system are, for example, the cathode components (the nickel matrix, which is deposited on the emitter surface); the carbonates, (which are sprayed on the nickel base and later converted to the emitting surface); and the final cathode processing. The nickel of the nickel matrix powder is analyzed and certified to be of the high purity level required. Carbonates are spectrographically analyzed and certified for highest purity levels. In addition, the associated solvents and binders are specifically formulated and controlled to meet the Phormat cathode requirements. Final processing of the cathode is extremely critical, and must take place in a non-reactive atmosphere. In addition, bake and exhaust schedules (tube outgassing) must be precisely performed to assure internal cleanliness of the tube.

Tube testing of the Airline Quality planar triodes has been set up as a separate program, itself a result of field life history and a comprehensive appraisal of the actual conditions under which tubes operate. To this end a series of definitive tests were scheduled for each AL tube to reflect environmental conditions and be predictive with regard to tube life under these conditions. Since failure mode analysis had indicated that cathode depletion was the typical cause for tube removal, test emphasis lies in the direction of assuring long term cathode activity. Grid-pulsed rf amplifier output vs variation in heater voltage and short and long pulse duration at reduced heater voltage provide two critical tests for cathode performance. Figure 1 describes a plot of a typical MIL-E specification 7815 and an ML-7815/AL tube showing the extended performance characteristics of the latter. Figure 2 shows comparable oscilloscope traces of the 4500 μsec pulse determining cathode activity under extremely high loading. As is evident, the ML-7815/AL pulse shows negligible current droop. Static tests to tightened amplification (mu) and transconductance (gm) specifications are performed as well as tests for plate current cut-off, interelectrode capacity and grid characteristics. Mechanical and high g shock testing are done on a sampling basis.

*"Simultaneous Cataphoretic and Electrolytic Deposition of Nickel for Cathode Bases of Reliable Electron Tubes", by P. F. Varadi and K. Ettre, *Journal of the Electrochemical Society,* Vol. 109, No. 4, April 1962.

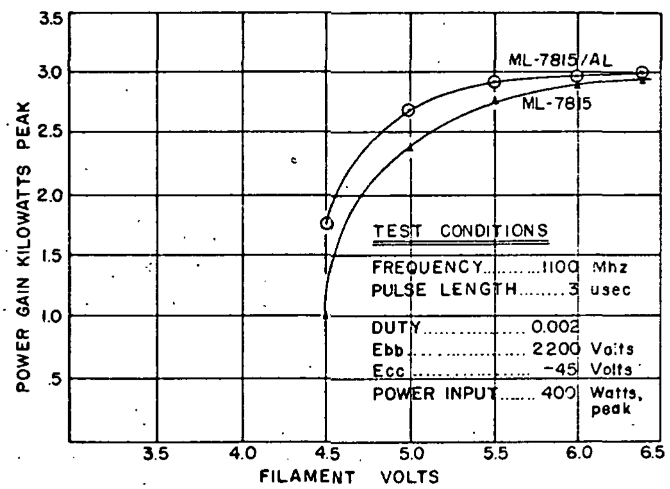


Figure 1 — Grid Pulsed RF Amplifier Output vs Heater Voltage.

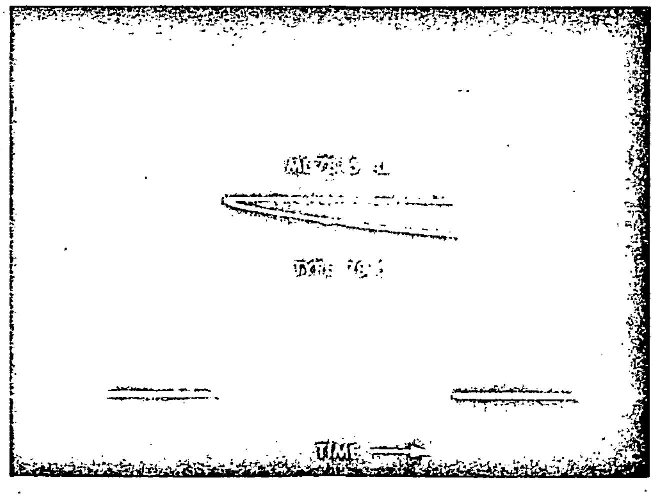


Figure 2 — Long Pulse Performance of Standard ML-7815 vs ML-7815/AL Tube.

APPENDIX E

Test Report No. NT-7523-11 No. of Pages 12

Contract # NAS-9-10399

Report of Test on

ELECTRON GUN

Environmental Testing

for

Ion Physics Corporation

Associated Testing Laboratories, Inc.

Burlington, Massachusetts

Date September 16, 1970

	Prepared	Checked	Approved
By	E. R. Mencow	R. Borghetti	E. E. Kulcsar
Signed	E R Mencow	R. Borghetti	E E Kulcsar
Date	9/21/70	9-18-70	[illegible]

SURVEILLANCE BY [illegible] Venezia QA DCASR Boston
21 Sep 70 DCRB 90N

Administrative Data

1.0 Purpose of Test:

To evaluate the performance of the Electron Gun when subjected to Environmental Testing in accordance with the referenced Specification and Procedures of this Test Report.

2.0 Manufacturer: Ion Physics Corporation
South Bedford Street
Burlington, Massachusetts 01803

3.0 Manufacturer's Type or Model No.: EE65-1

4.0 Drawing, Specification or Exhibit: In accordance with written and verbal instructions from Ion Physics Corporation.

5.0 Quantity of Items Tested: One (1) (S/N 3)

6.0 Security Classification of Items: Unclassified

7.0 Date Test Completed: September 14, 1970

8.0 Test Conducted By: Associated Testing Laboratories, Inc.
NEW ENGLAND DIVISION

9.0 Disposition of Specimens: Returned to Ion Physics Corporation

10.0 Abstract:

The submitted Electron Gun was subjected to Sinusoidal Vibration over the frequency range of 20 to 2000 Hz at levels up to ±6g's peak. The unit was vibrated in three mutually perpendicular axes. There was one sweep up from 20 to 2000 Hz in each axis. There was no visible damage incurred to the Electron Gun as a result of the Sinusoidal Vibration Test.

10.0 Abstract (continued)

The Electron Gun was subjected to Random Frequency Vibration Testing over the range of 20 - 2000 Hz at a PSD Level of $0.05g^2/Hz$ and an overall level of 10g's rms. The unit was subjected to the Random Vibration for a period of 10 seconds in each of its 3 mutually perpendicular axes. At the conclusion of the Random Vibration Test, there was no visible damage incurred to the Electron Gun.

The Electron Gun was subjected to a Shock Test in each of its 3 mutually perpendicular axes. A total of 6 blows was delivered to the unit, 1 in each direction of each axis. Each shock pulse approximated a half sine wave with a peak amplitude of 15g's and 15 millisecond time duration. There was no visible damage incurred to the Electron Gun as a result of the Shock Test.

SINUSOIDAL VIBRATION TEST

TEST PROCEDURE

The submitted Electron Gun was subjected to a Sinusoidal Vibration Test in accordance with written and verbal instructions from a Representative of Ion Physics Corporation. The following is a description of the test as it was performed.

The Electron Gun was securely attached to its Vibration Test fixture, which was then attached to the table of the Vibrator. The Electron Gun was then subjected to Sinusoidal Vibration over the frequency range of 20 to 2000 Hz at the levels given below:

TABLE I

Frequency (Hz)	Amplitude
20 - 500	±1g
500 - 2000	±6g's

The frequency range from 20 to 500 Hz was swept up in approximately 30 seconds and the frequency range from 500 - 2000 Hz was swept up in approximately 30 seconds. There was no return sweep.

The above procedure was performed in each of the unit's 3 mutually perpendicular axes. The Electron Gun was examined for damage after vibration in each axis.

TEST RESULTS

There was no visible damage incurred to the Electron Gun as a result of the Sinusoidal Vibration test.

RANDOM VIBRATION TEST

TEST PROCEDURE

The Electron Gun was subjected to Random Frequency Vibration Testing in accordance with written and verbal instructions from an Engineering Representative of Ion Physics Corporation. The following is a description of the test as it was performed.

The Electron Gun was secured to the Vibrator as previously described in the Sinusoidal Vibration Test Procedure. The unit was then subjected to the following Random Vibration Test:

Test Level

Frequency (Hz)	PSD Level (g^2/Hz)
20 - 2000	0.05

Overall Level = 10g rms

The above Random Vibration Test Levels were applied in each of three mutually perpendicular axes.

Prior to mounting the specimen to the Vibration Test fixture, equalization of the Random System was accomplished by means of a System containing 85 parallel band-pass filters with individual attenuators for spectrum shaping. Each filter had a maximum bandwidth of 25 Hz. The System also contained Monitoring Circuits with power spectral density meters which read directly in g^2/Hz. The System was first set-up in the closed loop mode. After programming in the specified test levels, the test spectrum was applied to the Shaker System. Where necessary, resetting of equalization controls was performed at those frequencies where the applied test level had deviated from that specified. The output of the Control Accelerometer with its associated normalizing filters was applied to the input of a Spectral Density Analyzer/Tracking Filter. The recorded power spectral density was displayed on an X-Y Plot. The tolerance of the displayed power

TEST PROCEDURE
(continued)

spectral density level was ±3db. The filters used for analyzing the random frequency test spectrum was as follows:

A. 20 Hz - from 20 to 100 Hz.

B. 50 Hz - from 100 to 2000 Hz.

After having assured that the test levels were within the stated tolerances, the System was shut-down and the Electron Gun was mounted to the test fixture.

The unit was subjected to the Test Levels for a period of 10 seconds in each of three mutually perpendicular axes.

The Electron Gun was examined for evidence of physical damage upon completion of each Random Vibration Exposure.

TEST RESULTS

There was no visible damage incurred to the Electron Gun as a result of the Random Vibration Test.

SHOCK TEST

TEST PROCEDURE

The Electron Gun was subjected to a Shock Test in accordance with written and verbal instructions from Ion Physics Corporation. The following is a description of the test as it was performed.

The Electron Gun was securely mounted to its fixture which, in turn, was mounted to the carriage of the Shock Machine. The unit was then subjected to a total of 6 blows, 1 in each direction of three mutually perpendicular axes. The magnitude of the shock pulse was 15g's, the time duration was 15 milliseconds, and the wave form was half sine wave. At the end of the test the unit was examined for external mechanical damage.

TEST RESULTS

There was no visible damage incurred to the Electron Gun as a result of the Shock Test.

LIST OF APPARATUS

Item	Manufacturer	Model No.	Accuracy	Calibration Date	Calibration Date Due
Vibration System	MB Electronics	C-60	±2%Freq. ±5%Ampl.	7-9-70	10-9-70
Accelerometer	Endevco Corporation	2215-E	±5%	7-24-70	10-24-70
Automatic Spectral Density Equalizer/Analyzer	Ling Electronics	ASDE-80	±5%	8-20-70	9-20-70
Analyzer Console	Associated Testing Laboratories, Inc. (NED)	135	±5%	9-3-70	10-3-70
Timer	Dimco-Gray Co.	165	±1sec/hr	7-13-70	1-13-70
Shock Machine	Avco Corporation	110 Model -3	N/A	Before Use	
Shock Console	Associated Testing Laboratories, (NED)	333	±5%	7-10-70	10-10-70
Oscilloscope	Tektronix	564	±3%	6-26-70	9-26-70
Camera	Hewlett-Packard	196A	N/A	N/A	N/A

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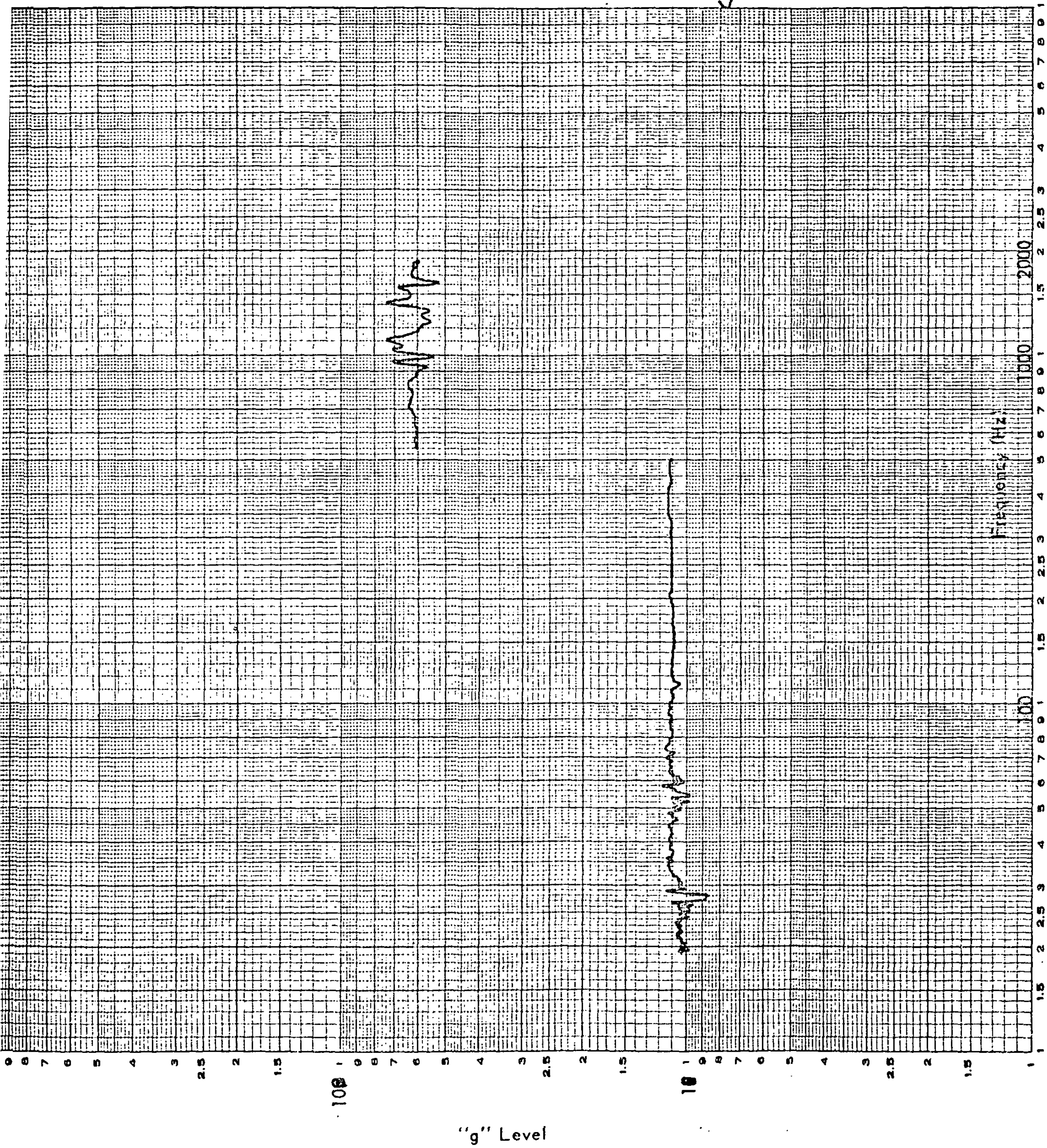
Wayne, New Jersey 07470
Burlington, Massachusetts 01803

SINUSOIDAL VIBRATION ANALYSIS

b Number NT-7523 Customer Ion Physics Corporation Date 9-14-70

ecimen P/N EE65-1 Specimen S/N 3 Test Temp. Room Ambient

Axis 1st Lateral Technician R. Borghetti



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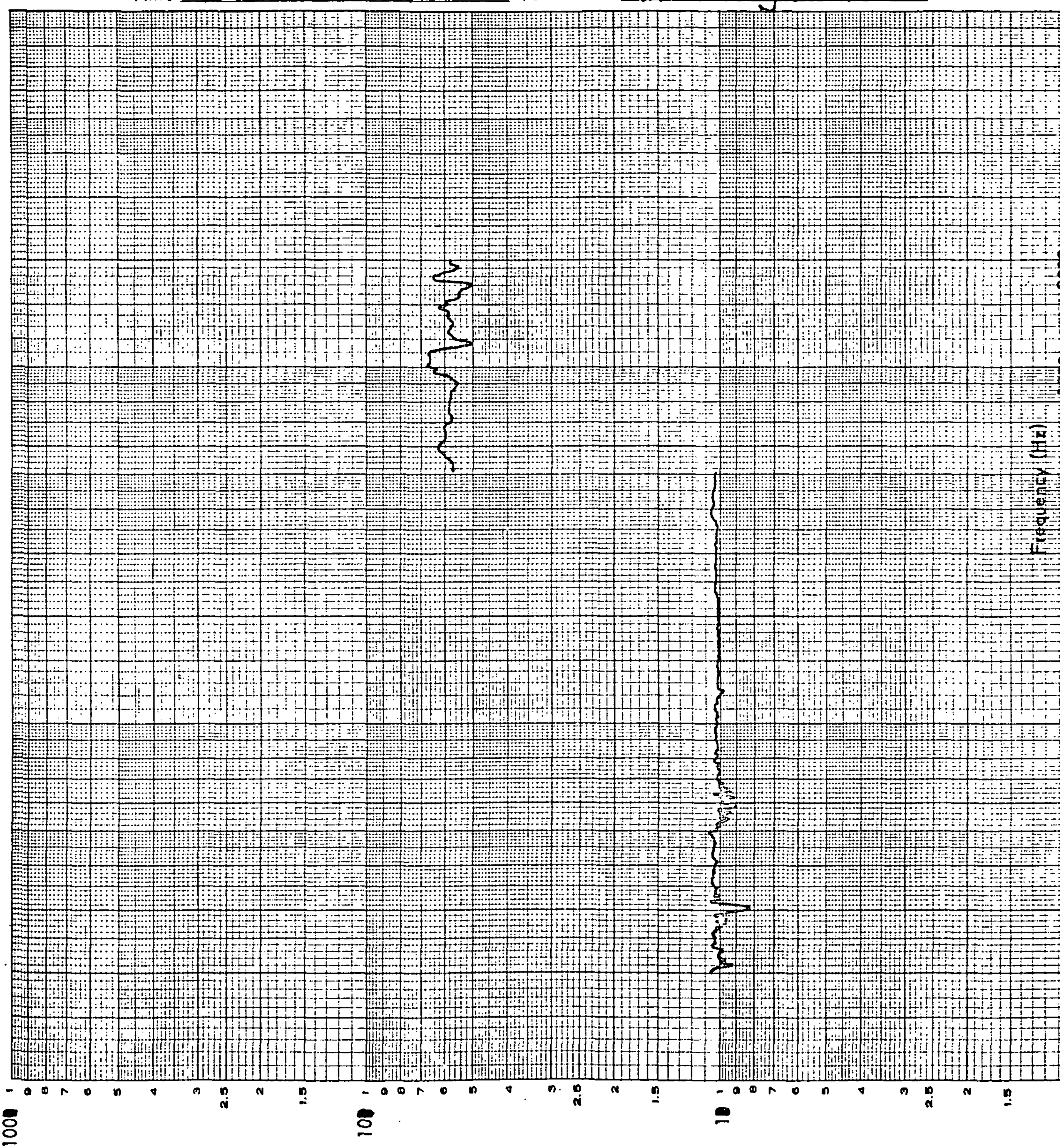
SINUSOIDAL VIBRATION ANALYSIS

Job Number NT-7523 Customer Ion Physics Corporation Date 9-14-70

Specimen P/N EE65-1 Specimen S/N 3 Test Temp. Room Ambient

Axis 2nd Lateral Technician R. Borghetti



"g" Level

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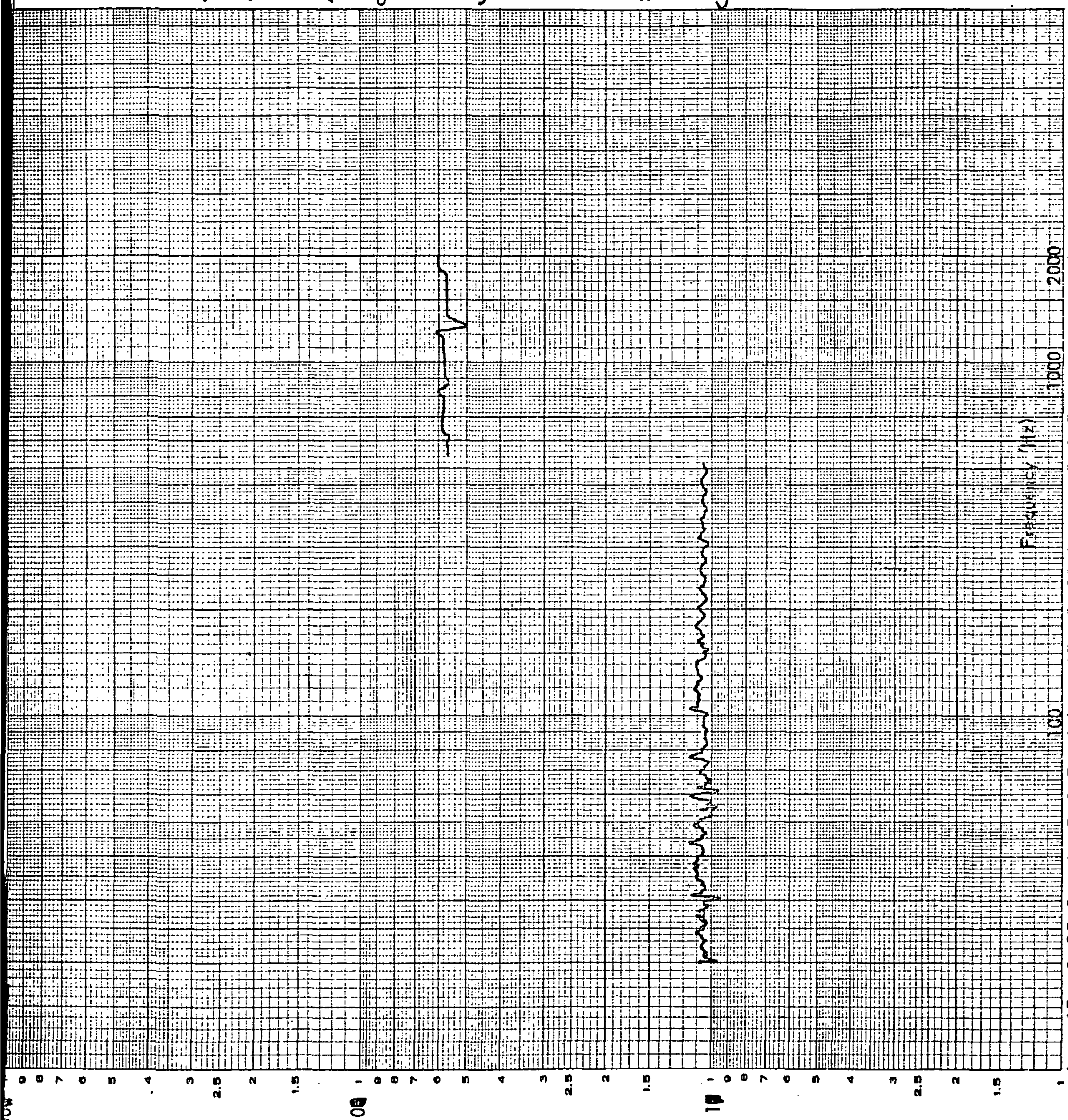
SINUSOIDAL VIBRATION ANALYSIS

Job Number NT-7523 Customer Ion Physics Corporation Date 9-14-70

Specimen P/N EE65-1 Specimen S/N 3 Test Temp. Room Ambient

Axis Vertical (longitudinal) Technician R. Borghetti



"g" Level

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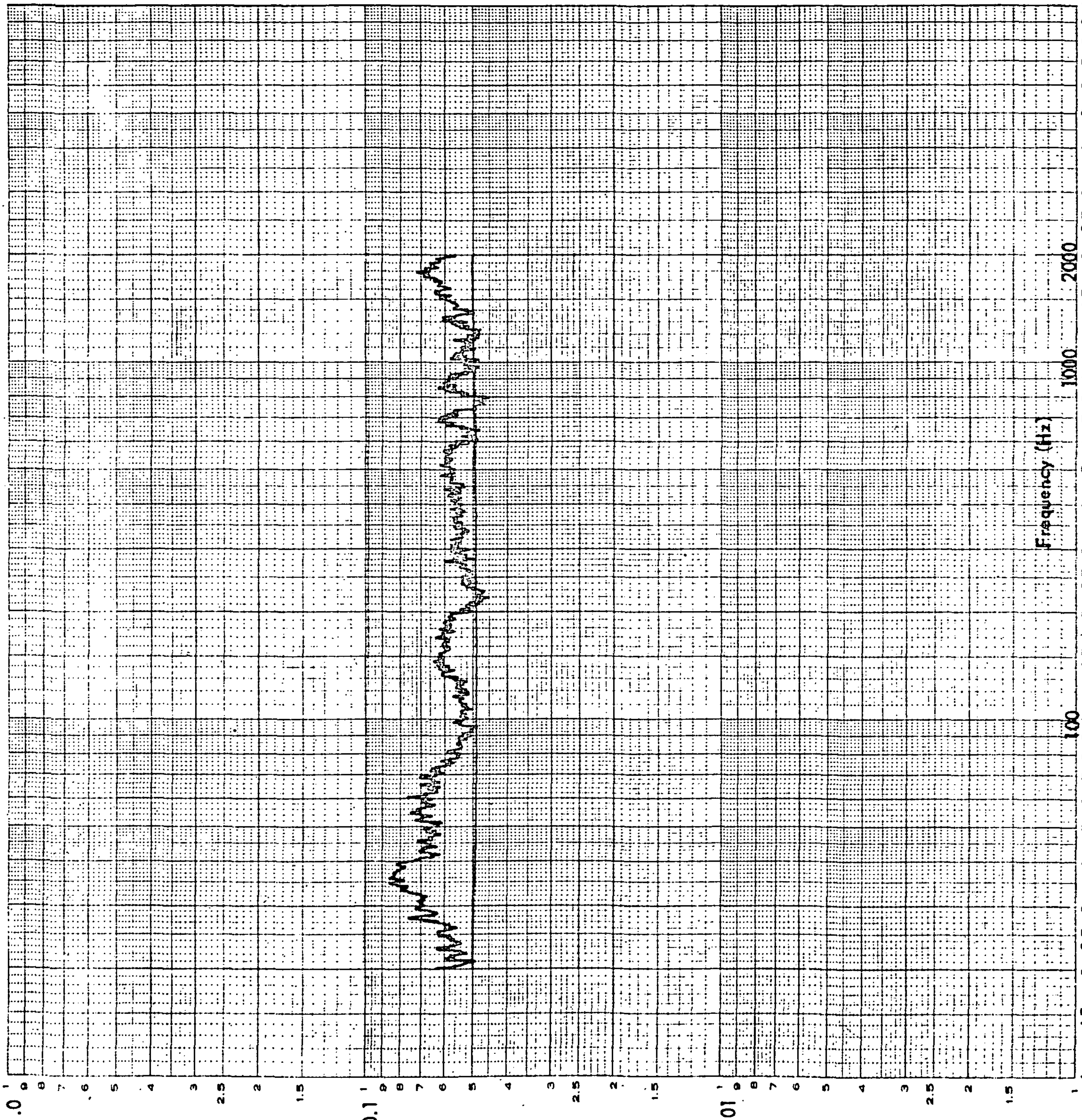
RANDOM VIBRATION ANALYSIS

Job Number NT-7523 Customer Ion Physics Corp. Date 9-14-70
Specimen P/N EE 65-1 Specimen S/N 3 Test Temp. Room Ambient
Bw. Analyzed Filter No. 1 20 to 100 Hz, Bw. Analyzed Filter No. 2 100 to 2000 Hz
Analyzing Filter No. 1 20 Hz Analyzing Filter No. 2 50 Hz
Vibration Axis Vertical (Longitudinal) Technician R. Borghetti



Spectral Density Level X 10 - (g^2/Hz)

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RANDOM VIBRATION ANALYSIS

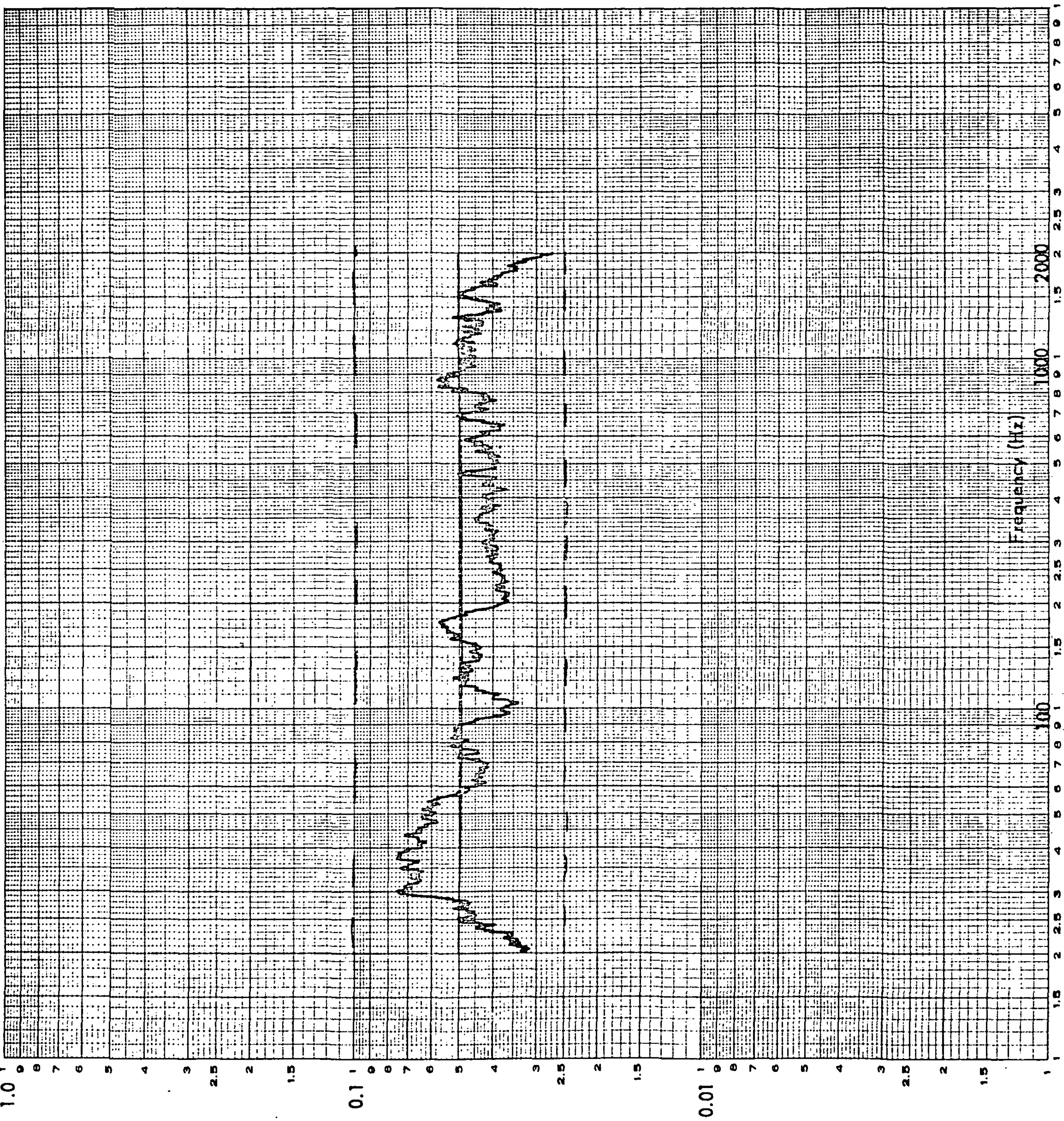
Job Number NT-7523 Customer Ion Physics Corp Date 9-14-70

Specimen P/N EE65-1 Specimen S/N 3 Test Temp. Room Ambient

Bw. Analyzed Filter No. 1 20 to 100 Hz, Bw. Analyzed Filter No. 2 100 to 2000 Hz

Analyzing Filter No. 1 20 Hz Analyzing Filter No. 2 50 Hz

Vibration Axis 1st & 2nd Lateral Technician R. Borghetti



Spectral Density Level X 10 - (g^2/Hz)

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Test Report No. NT-7614-11 No. of Pages 12

Contract No.: NAS-9-10399

Report of Test on

ELECTRON GUN

Environmental Testing

for

Ion Physics Corporation

Associated Testing Laboratories, Inc.

Burlington, Massachusetts

Date October 13, 1970

	Prepared	Checked	Approved
By	E. R. Mencow	R. Borghetti	E. E. Kulcsar
Signed	E R Mencow	R. Borghetti	E. E. Kulcsar
Date	10/14/70	10-16-70	10-16-70

Surveillance by: A P Venezia QCA DCASR Boston

P.O. 08026/505
ORIG. NT. 7523
16 Oct 70 DCRB-QON

Administrative Data

1.0 Purpose of Test:

To evaluate the performance of the Electron Gun when subjected to Environmental Testing in accordance with the referenced Specification and Procedures of this Test Report.

2.0 Manufacturer:

Ion Physics Corporation
South Bedford Street
Burlington, Massachusetts 01803

3.0 Manufacturer's Type or Model No.:

EE65-1

4.0 Drawing, Specification or Exhibit:

In accordance with written and verbal instructions from Ion Physics Corporation.

5.0 Quantity of Items Tested:

One (1) (S/N 4)

6.0 Security Classification of Items:

Unclassified

7.0 Date Test Completed:

October 8, 1970

8.0 Test Conducted By:

Associated Testing Laboratories, Inc.
NEW ENGLAND DIVISION

9.0 Disposition of Specimens:

Returned to Ion Physics Corporation

10.0 Abstract:

The submitted Electron Gun was subjected to Sinusoidal Vibration over the frequency range of 20 to 2000 Hz at levels up to ±6g's peak. The unit was vibrated in three mutually perpendicular axes. There was one sweep up from 20 to 2000 Hz in each axis. There was no visible damage incurred to the Electron Gun as a result of the Sinusoidal Vibration Test.

10.0 Abstract (continued)

The Electron Gun was subjected to Random Frequency Vibration Testing over the range of 20 to 2000 Hz at a PSD Level of $0.05g^2/Hz$ and an overall level of 10g's rms. The unit was subjected to the Random Vibration for a period of 10 seconds in each of its 3 mutually perpendicular axes. At the conclusion of the Random Vibration Test, there was no visible damage incurred to the Electron Gun.

The Electron Gun was subjected to a Shock Test in each of its three mutually perpendicular axes. A total of 6 blows was delivered to the unit, 1 in each direction of each axis. Each shock pulse approximated a half sine wave with a peak amplitude of 15g's and 15 millisecond time duration. There was no visible damage incurred to the Electron Gun as a result of the Shock Test.

LIST OF APPARATUS

Item	Manufacturer	Model No.	Accuracy	Calibration Date	Calibration Date Due
Vibration System	Ling Electronics	A175	±2%Freq. ±5%Ampl.	7-28-70	10-28-70
Accelerometer	Endevco Corporation	2215-E	±5%	7-24-70	10-24-70
Automatic Spectral Density Equalizer/ Analyzer	Ling Electronics	ASDE-80	±5%	8-20-70	9-20-70
Analyzer Console	Associated Testing Laboratories, Inc. (New England Division)	135	±5%	10-5-70	11-5-70
Timer	Dimco-Gray Company	165	±1sec/hr.	7-13-70	1-13-71
Shock Machine	Avco Corporation	110 Model -3	N/A	Before Use	
Shock Console	Associated Testing Laboratories, Inc. (New England Division)	333	±5%	7-10-70	10-10-70
Oscilloscope	Tektronix	564	±3%	9-10-70	12-10-70

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Burlington, Massachusetts 01803

SINUSOIDAL VIBRATION TEST

TEST PROCEDURE

The submitted Electron Gun was subjected to a Sinusoidal Vibration Test in accordance with written and verbal instructions from a Representative of Ion Physics Corporation. The following is a description of the test as it was performed.

The Electron Gun was securely attached to its Vibration Test fixture, which was then attached to the table of the Vibrator. The Electron Gun was then subjected to Sinusoidal Vibration over the frequency range of 20 to 2000 Hz at the levels given below:

TABLE I

Frequency (Hz)	Amplitude
20 - 500	±1g
500 - 2000	±6g's

The frequency range from 20 to 500 Hz was swept up in approximately 30 seconds and the frequency range from 500 to 2000 Hz was swept up in approximately 30 seconds. There was no return sweep.

The above procedure was performed in each of the units' three mutually perpendicular axes. The Electron Gun was examined for damage after vibration in each axis.

TEST RESULTS

There was no visible damage incurred to the Electron Gun as a result of the Sinusoidal Vibration Test.

RANDOM VIBRATION TEST

TEST PROCEDURE

The Electron Gun was subjected to Random Frequency Vibration Testing in accordance with written and verbal instructions from an Engineering Representative of Ion Physics Corporation. The following is a description of the test as it was performed.

The Electron Gun was secured to the Vibrator as previously described in the Sinusoidal Vibration Test Procedure. The unit was then subjected to the following Random Vibration Test:

TEST LEVEL

Frequency (Hz)	PSD Level (g^2/Hz)
20 - 2000	0.05

Overall Level = 10g rms

The above Random Vibration Test levels were applied in each of three mutually perpendicular axes.

Prior to mounting the specimen to the Vibration Test fixture, equalization of the Random System was accomplished by means of a System containing 85 parallel band-pass filters with individual attenuators for spectrum shaping. Each filter had a maximum bandwidth of 25 Hz. The System also contained Monitoring circuits with power spectral density meters which read directly in g^2/Hz. The System was first set-up in the closed loop mode. After programming in the specified test levels, the test spectrum was applied to the shaker system. Where necessary, resetting of equalization controls was performed at those frequencies where the applied test level had deviated from that specified. The output of the Control Accelerometer with its associated normalizing filters was applied to the input of a Spectral Density Analyzer/Tracking Filter. The recorded power spectral density was displayed on an X-Y Plot. The tolerance of the displayed power

RANDOM VIBRATION TEST

TEST PROCEDURE (continued)

spectral density level was ±3db. The filters used for analyzing the random frequency test spectrum were as follows:

A. 20 Hz - from 20 to 50 Hz.

B. 50 Hz - from 50 to 2000 Hz.

After having assured that the test levels were within the stated tolerances, the System was shut-down and the Electron Gun was mounted to the test fixture.

The unit was subjected to the Test Levels for a period of 10 seconds in each of three mutually perpendicular axes.

The Electron Gun was examined for evidence of physical damage upon completion of each Random Vibration Exposure.

TEST RESULTS

There were no visible damage incurred to the Electron Gun as a result of the Random Vibration Test.

SHOCK TEST

TEST PROCEDURE

The Electron Gun was subjected to a Shock Test in accordance with written and verbal instructions from Ion Physics Corporation. The following is a description of the test as it was performed.

The Electron Gun was securely mounted to its fixture which, in turn, was mounted to the carriage of the Shock Machine. The unit was then subjected to a total of 6 blows, 1 in each direction of three mutually perpendicular axes. The magnitude of the shock pulse was 15g's, the time duration was 12 milliseconds, and the wave form was half sine wave. At the end of the test the unit was examined for external mechanical damage.

TEST RESULTS

There was no visible damage incurred to the Electron Gun as a result of the Shock Test.

RANDOM VIBRATION ANALYSIS

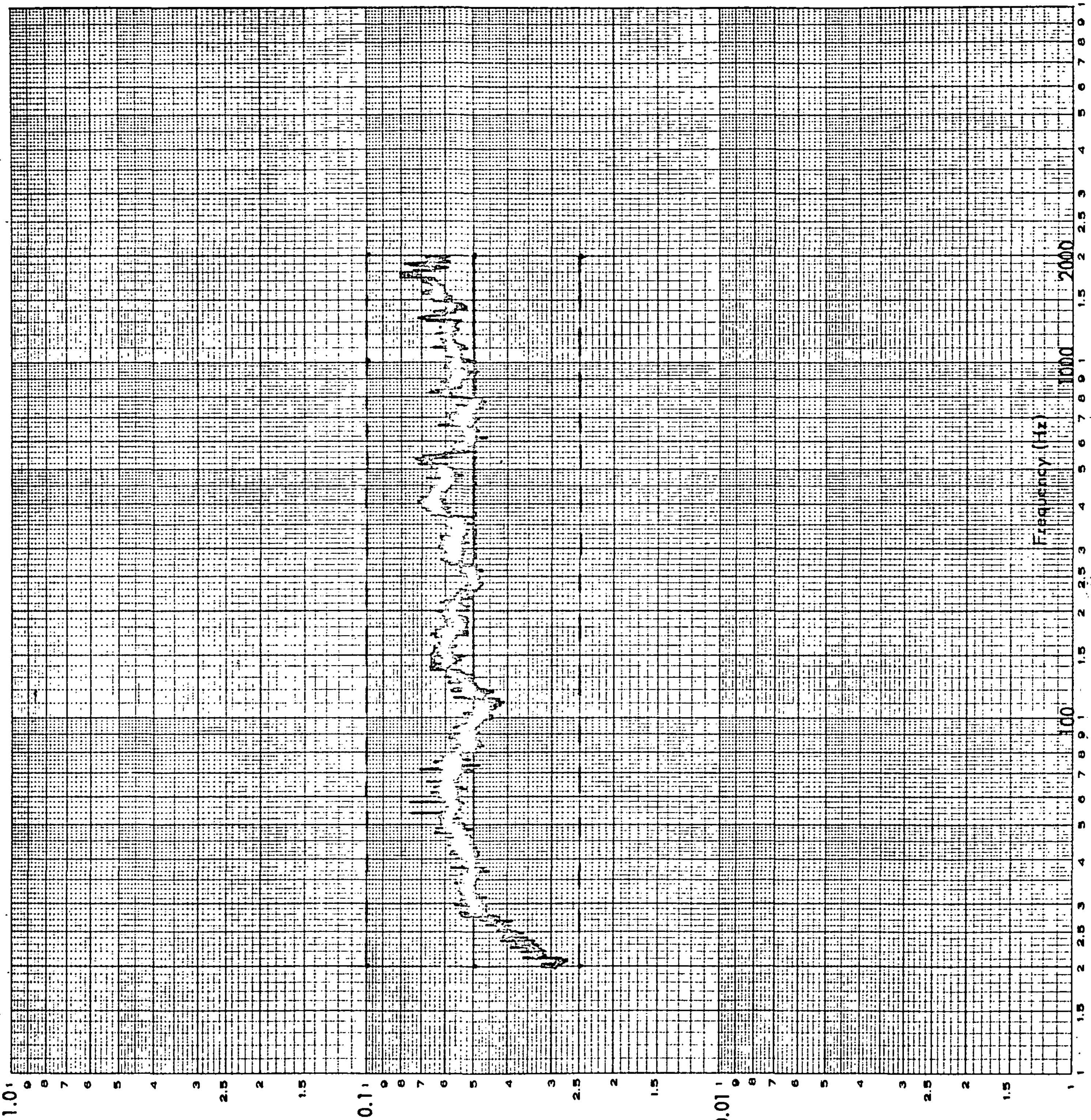
Job Number NT-7614 Customer Ion Physics Corp. Date 10-8-70

Specimen P/N EE 65-1 Specimen S/N 4 Test Temp. Room Ambient

Bw. Analyzed Filter No. 1 20 to 50 Hz, Bw. Analyzed Filter No. 2 50 to 2000 Hz

Analyzing Filter No. 1 20 Hz Analyzing Filter No. 2 50 Hz

Vibration Axis Vertical (longitudinal) Technician R. Borghetti



Spectral Density Level X 10 - (g^2/Hz)

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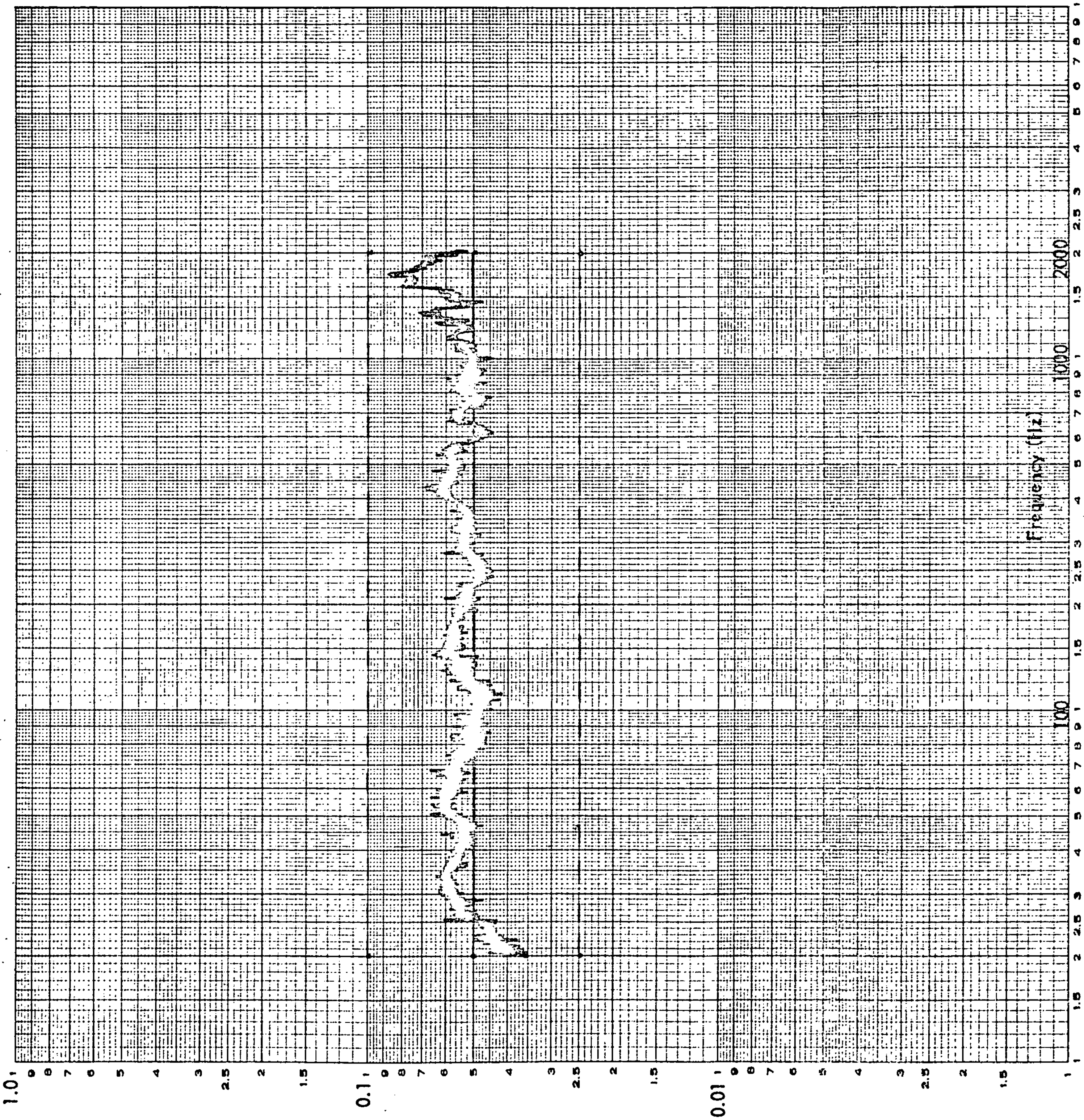
RANDOM VIBRATION ANALYSIS

Job Number NT-7614 Customer Ion Physics Corp. Date 10-8-70
Specimen P/N EE65-1 Specimen S/N 4 Test Temp. Room Ambient
Bw. Analyzed Filter No. 1 20 to 50 Hz, Bw. Analyzed Filter No. 2 50 to 2000 Hz
Analyzing Filter No. 1 20 Hz Analyzing Filter No. 2 50 Hz
Vibration Axis 1st & 2nd Lateral Technician R. Borghetti



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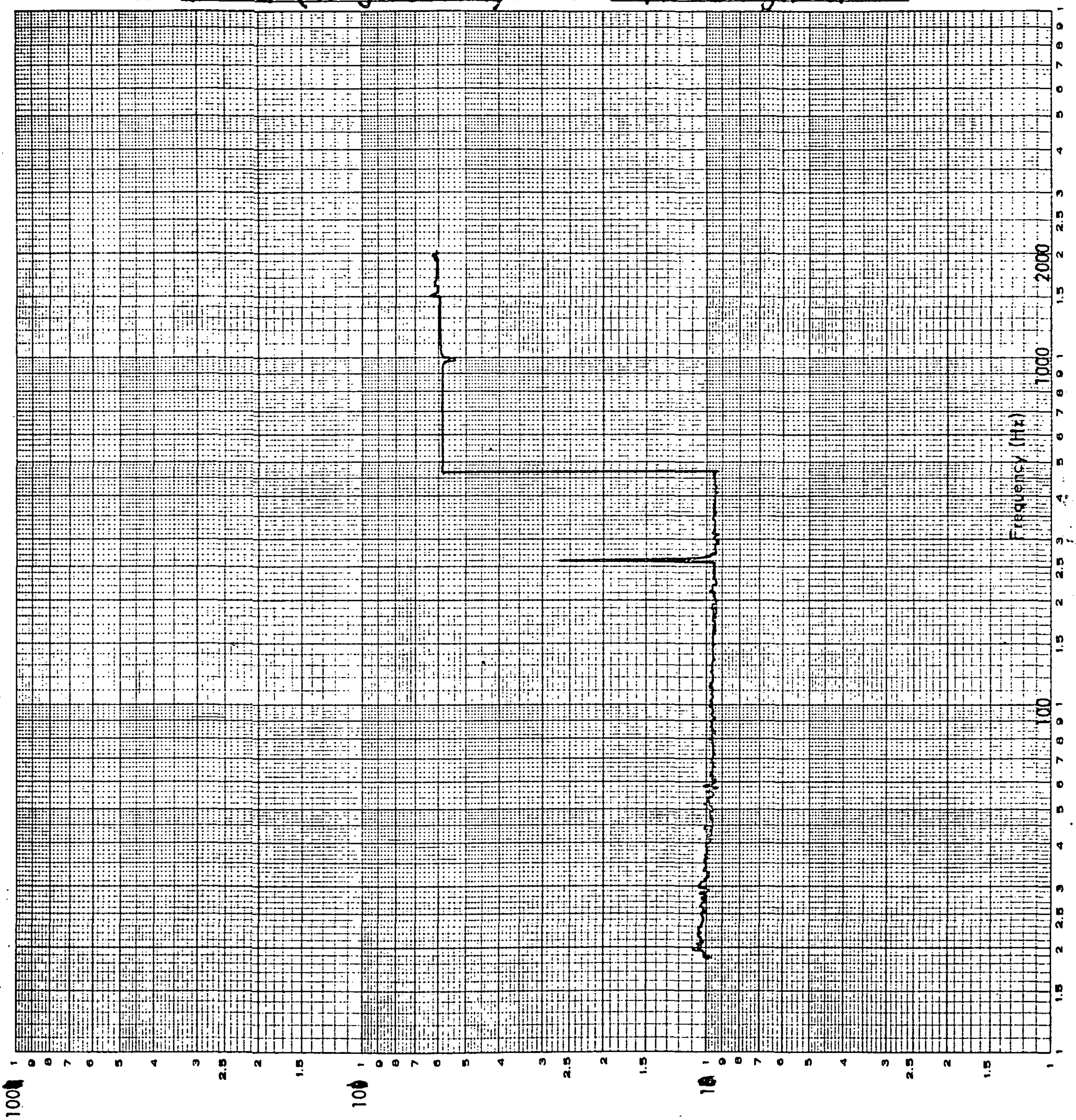
SINUSOIDAL VIBRATION ANALYSIS

Job Number NT-7614 Customer Ion Physics Corporation Date 10-8-70

Specimen P/N EE65-1 Specimen S/N 4 Test Temp. Room Ambient

Axis Vertical (longitudinal) Technician R. Borghetti



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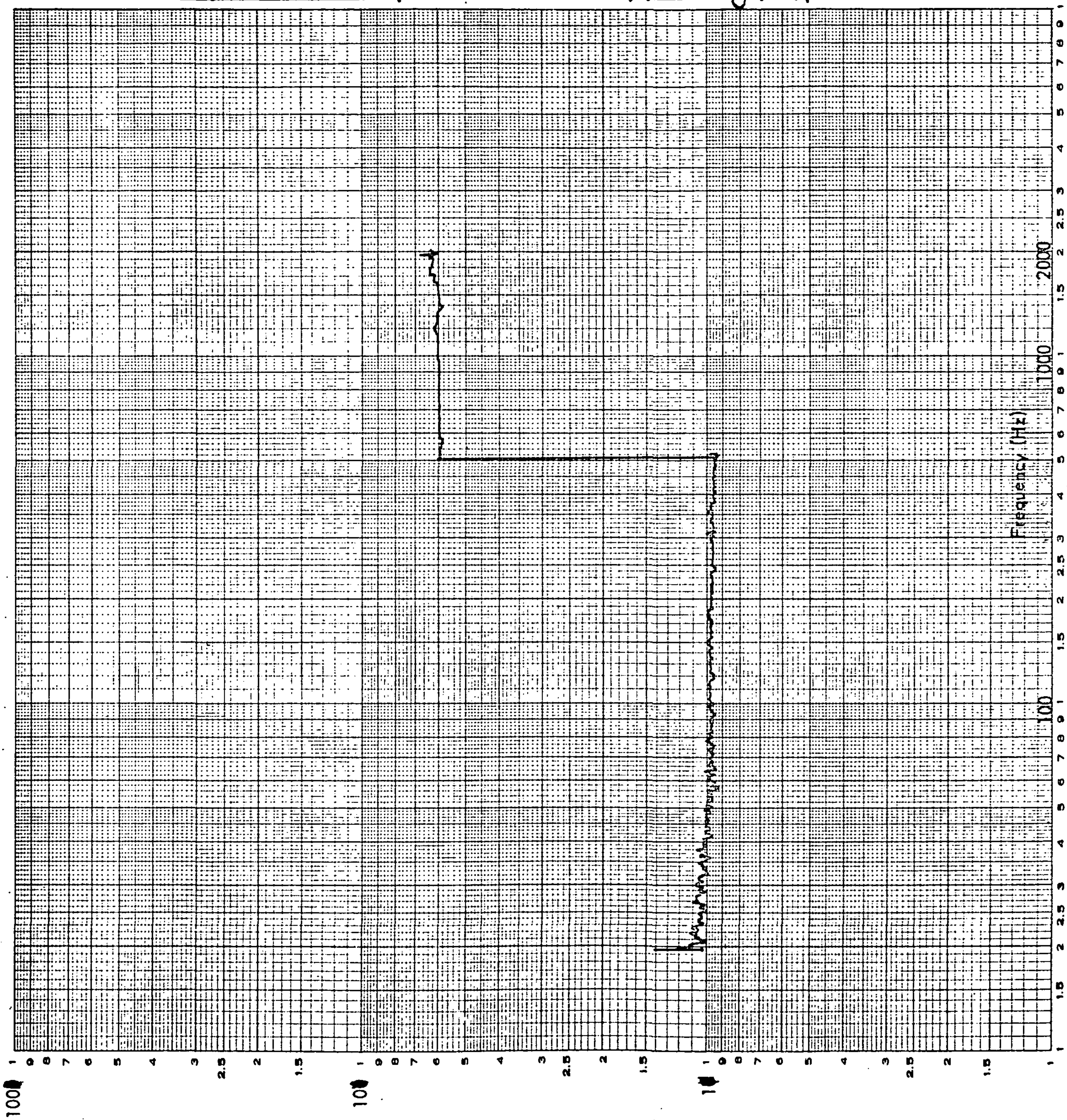
SINUSOIDAL VIBRATION ANALYSIS

Job Number NT-7614 Customer Ion Physics Corporation Date 10-8-70

Specimen P/N EE65-1 Specimen S/N 4 Test Temp. Room Ambient

Axis 1st Lateral Technician R. Borghetti



"g" Level

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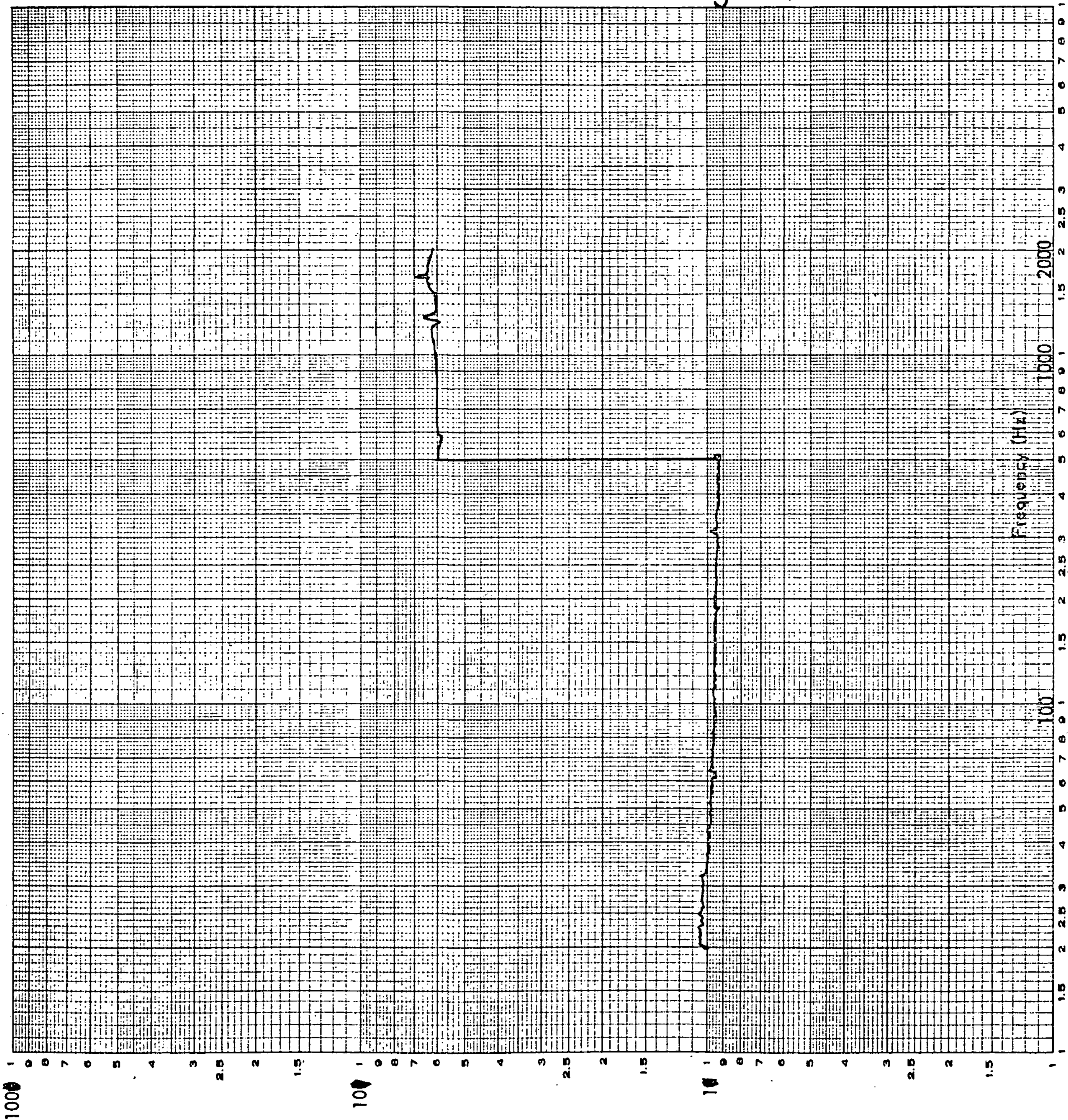
SINUSOIDAL VIBRATION ANALYSIS

Job Number NT-7614 Customer Ion Physics Corporation Date 10-8-70

Specimen P/N EE65-1 Specimen S/N 4 Test Temp. Room Ambient

Axis 2nd Lateral Technician R. Borghetti



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NO. 9-51

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